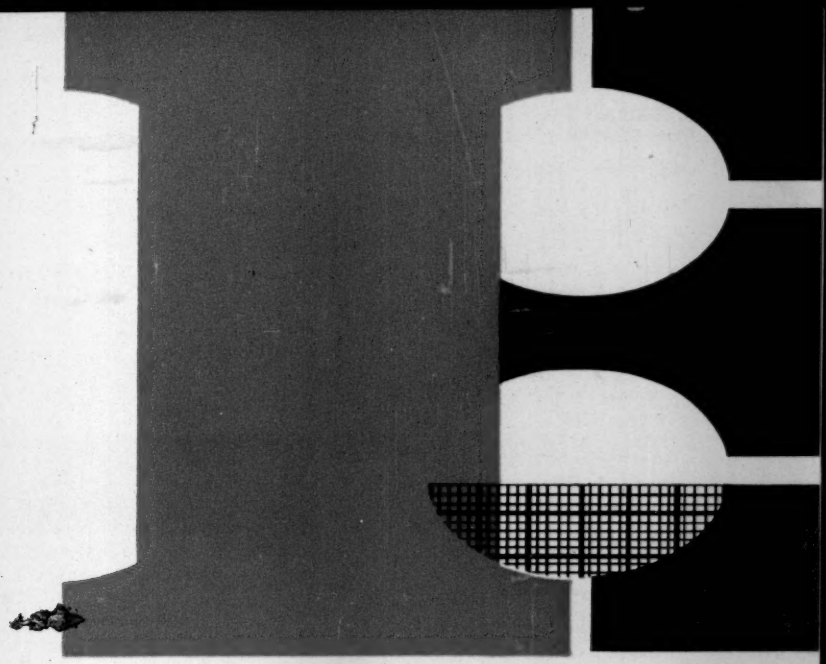

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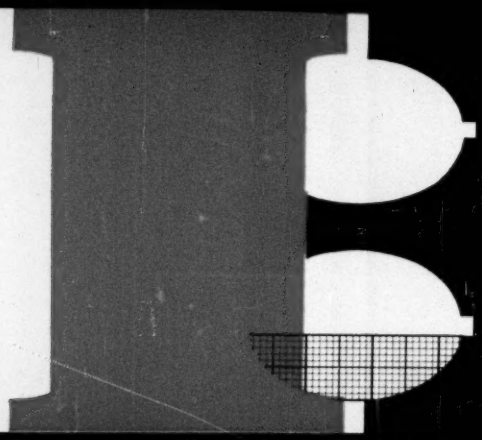

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Nonproductive Work as a Factor in the Economic Division of Labor

by **MAURICE D. KILBRIDGE**

Professor of Management, University of Chicago, Graduate School of Business

THE PRINCIPLE of the division of labor when applied to the mass assembly of manufactured items takes the form of the assembly line. Operators are stationed along the line on which moves the frame or chassis of the product being assembled. The total job is broken down into elements of work and assigned to the various stations on the line. As the product progresses down the line each operator adds to it his share of the work. The technique is referred to as "progressive assembly" and the time the product spends at each work station is called the "cycle time."

Minute job specialization on assembly lines has been practiced in this way for fifty years on the grounds that it is economically and technologically desirable. The reason is that certain costs, such as of wages and training, are reduced as the job is broken down and deskilled. This is true to a point, but it is possible that it can be carried too far. Although some costs decrease as job breakdown proceeds, other costs, such as the cost of nonproductive work, will eventually increase, and beyond an optimum point the total assembly cost may turn upward, defeating the purpose of further job specialization. Many factors join in determining this optimum point. They are economic, technological, and psychological, and they vary with specific situations. The search for an analytical method of determining the optimum extent to which the assembly task should be broken down is called the "cycle time problem" (1).

In this presentation only one determinant of the optimum cycle time is discussed. This is the amount of nonproductive work induced by the division of labor. Nonproductive work, in the context of progressive assembly lines, takes the form of handling of product and tools and operator movement to and from the work position.

The research for this article was done on television chassis assembly lines in the consumer electronics industry. The cycle times most commonly used in this industry range from one to three minutes. This study shows that within this range the cost of nonproductive work is minimized for powered[1] conveyor assembly lines and near minimized for manual conveyor lines. For cycle times larger than this range nonproductive work remains virtually constant at between 4 and 5 percent of total work. For cycle times of less than one minute, in the case of powered conveyor lines, and of less than two minutes in the case of nonpowered conveyor lines, the percentage of nonproductive time increases sharply.

THE STUDY

The data for this study were gathered in two Chicago companies in the radio and television industry. In each company operations analysis sheets were available showing each element of work performed on the line and the standard time required to perform it. The standard times in each case were derived from a predetermined time system of generally accepted validity. This assured consistency of standard times for all similar elements of work. From the analysis sheets it was possible to sort out the productive from the nonproductive work elements. The elements of handling time and return-to-position time were separated from the productive elements of work. This was done for the same lines running the same product at a variety of cycle times. The func-

[1] Powered conveyor lines are motor-driven belt conveyors which move the product laterally past the operators at a uniform speed. The entire line can be speeded up or slowed down by adjusting the drive motor, but individual operators have no control over the speed of the conveyor. Manual conveyor lines, called "pull-up-and-push lines," are not driven. They consist of stationary rollers or smooth sheet metal surfaces along which the product is slid by the operators. Manual conveyor lines therefore require more operator handling of the product than do powered conveyor lines. In neither case is the product picked up and moved off the conveyor to a separate work platform. Assembly work is done directly on the conveyor.

TABLE 1

Analysis of Productive and Nonproductive Work in the Assembly of a 21" TV Chassis on Powered Conveyor Lines for Various Assembly Cycles (Company 1)

(Time in Minutes)

Number of Stations or Operators 1	Productive Work Content Time 2	Nonproductive Work Content Time					Total Work Content Time 8	% Nonproductive of Total Time 9	Cycle Time 10
		Product Handling 3	Tool Handling 4	Return to Position 5	Extra Component Allowance 6	Total Nonproductive Work Content Time 7			
1	59.67	.69	1.51	—	.70	2.90	62.57	4.63	62.57
2	59.67	.75	1.51	—	.70	2.96	62.63	4.73	31.32
3	59.67	.80	1.51	—	.70	3.01	62.68	4.80	20.89
4	59.67	.72	1.51	.02	.70	2.95	62.62	4.71	15.66
5	59.67	.72	1.51	.03	.70	2.96	62.63	4.73	12.53
10	59.67	.72	1.51	.08	.47	2.78	62.45	4.45	6.30
15	59.67	.72	1.51	.13	.23	2.59	62.26	4.16	4.15
20	59.67	.72	1.51	.18	—	2.41	62.08	3.88	3.10
30	59.67	.72	1.42	.28	—	2.42	62.09	3.90	2.07
60	59.67	.66*	1.34	.57	—	2.57	62.24	4.13	1.04
143	59.67	.78	1.37	1.39	—	3.54	63.21	5.60	0.44

* The apparent inconsistency of product handling time for the 60-man line is due to the use of an assembly fixture at the start of the line. At a one minute cycle handling of this fixture is minimized.

tional relationship between length of cycle and the amount of nonproductive work was then determined. This was done for eleven powered conveyor cases and eleven manual conveyor cases in the first company and for five powered conveyor cases in the second company. The results are similar for the two companies.

The work performed in all cases in Company 1 was the assembly of the chassis of a twenty-one inch television set. The total work content time[2] was about 62 minutes. The work performed on the five lines of Company 2 was the assembly of the chassis of a smaller television set with a work content time of about 52 minutes. Chassis assembly consists of placing and fastening small electronic components, lacing them together with wires and soldering the wire connections. The work is done mostly by women seated side by side at the line.

The first step in the analytical work was to go through the operation analysis sheets and sort out productive from nonproductive work. The nonproductive work was classified under four headings:

1. Product handling.
2. Tool handling.
3. Return-to-position.
4. Station-size allowance.

Product handling includes all handling of the major product (but not components) by the assembly workers. This handling usually takes the form of putting the product on and off the line, placing it in, or on, the assembly fixture, moving it between stations (when this is done by hand as on manual conveyor lines), positioning the product, etc. This class of handling also includes the time spent handling fixtures, jigs, and other devices used to hold or transport the product.

Tool handling includes picking up and putting aside, or grasping and bringing to position in the case of suspended tools, all hand tools and small instruments of production. These include, for example, solder irons, pliers, wrenches, sand paper, steel wool, paint and dusting brushes. This class does not include tools, such as jigs and fixtures, used to hold or position the product. These are included under product handling.

Return-to-position time is the time required for an operator on a powered conveyor line to return, after finishing work on a unit of product, to her original position to start work on the next unit. In the case of standing assembly work the operator may walk with the product several steps along the line while performing the job. In seated assembly work time is spent swinging the upper body from one unit to the next and in searching for the starting point of the next assembly cycle. This

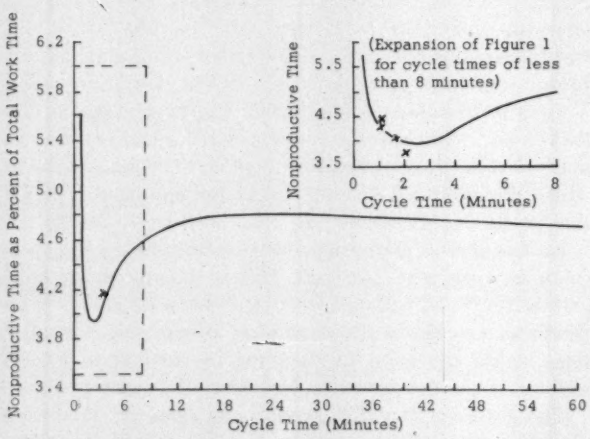

FIGURE 1. Nonproductive Time as Percent of Total Work Time for Various Assembly Cycle Lengths on Powered Conveyor Lines.

[2] The "total work content time" is the time required to perform all elements of assembly work on the line. The "productive work content time" is the time required to perform all the productive work elements, such as "pick up and insert tube." The "nonproductive work content time" is the time required to perform all the nonproductive work, such as "reach to next chassis." The productive work content time and nonproductive work content time together comprise the total work content time.

time is over and above that required to move from one component to another within the same unit of product and therefore must be considered a time cost associated with the breakdown of work. This is found only on powered conveyor lines, since on manual lines it is absorbed in the operation of pulling the next chassis into position.

Station-size allowance is a time allowance given to compensate the assembly operator for the increased distance she must move or reach to pick up and bring into position the piece parts she assembles. As the cycle time and the volume of work done at each station increase, so does the number of different components used at each station. As the storage area required to hold these components gets larger, the average reach and move distance to get components also increases.

RESULTS: COMPANY 1

Table 1 shows the total productive and nonproductive work in the assembly of a twenty-one inch television chassis on powered conveyor lines for various assembly cycles. The productive work content time, Column *2*, and the total nonproductive work content time, Column *7*, add to give the total work content time, Column *8*. Column *9* shows the nonproductive time as a percent of total time. The cycle time[3] of Column *10* is found by dividing the total work content time, Column *8*, by the number of stations or operators, Column *1*.

In Figure 1 the nonproductive time as percent of total time, Column *9*, is plotted as a function of cycle time, Column *10*. (That part of the curve of Figure 1 corresponding to cycle times of less than eight minutes is expanded in the insert in the upper corner. The *X*'s plotted near the curve pertain to the Company 2 case and will be explained later.) This figure shows that nonproductive time on powered conveyor lines in this company is minimal for cycle times of about 2½ minutes where it reaches a low of about 3.8 percent of the total work time. From there it rises about one percent as it approaches a six minute cycle and remains virtually constant at about 4.7 percent as the cycle time increases to its ultimate maximum of 63 minutes.

On the other hand, as the cycle time decreases beyond 2½ minutes, the percent of nonproductive work increases gradually to about 4.1 percent at a one minute cycle and then less gradually for cycle times of less than one minute. At a one-half minute cycle it reaches about 5.6 percent and, by extrapolation of the curve, would perhaps reach about 10 percent for a one-quarter minute cycle.

A dip appears in the curve of Figure 1 between cycle times of about one to six minutes. Although it looks dramatic because of the scale used, it represents a drop of less than one percent in nonproductive time. This dip is caused by the decreasing station-size allowance time for the compact work stations that result from the use of short cycle times. For cycle times of less than one minute this savings in station-size allowance time is offset by an increase in other nonproductive time which moves the curve up sharply. For cycle times of over six minutes the four kinds of nonproductive work fall into a total balance. Decreases in one are offset by increases in another and the total remains practically constant thereafter.

For cycle times ranging from about 63 minutes (a one-man operation) to about 0.40 minutes (143 operators) the total nonproductive time varies by only two percent. Within this range of cycle times it has a maximum of 5.7 percent and a minimum of 3.8 percent. Only when the cycle time gets very small, about one-quarter minute or less, does nonproductive work become an important cost factor. This point is beyond that to which assembly work in this industry can normally be broken down due to the existence of irreducible work elements of duration longer than one-quarter minute. Therefore it would seem that, generally speaking, where work in this industry is done on powered conveyor lines, nonproduc-

[3] This value is not precisely equal to the actual cycle time because it does not consider balance delay time, or time lost through imperfect division of work among the operators. However, it is close enough to the cycle time for purposes of this study.

TABLE 2

Analysis of Productive and Nonproductive Work in the Assembly of a 21" TV Chassis on Nonpowered Conveyor Lines for Various Assembly Cycles (Company 1)

(Time in Minutes)

Number of Stations or Operators *1*	Productive Work Content Time *2*	Nonproductive Work Content Time				Total Work Content Time *7*	% Nonproductive Time of Total Work Time *8*	Cycle Time *9*
		Product Handling *3*	Tool Handling *4*	Extra Component Allowance *5*	Total Nonproductive Work Content Time *6*			
1	59.67	.69	1.51	.70	2.90	62.57	4.63	62.57
2	59.67	.75	1.51	.70	2.96	62.63	4.73	31.32
3	59.67	.80	1.51	.70	3.01	62.68	4.80	20.90
4	59.67	.85	1.51	.70	3.06	62.73	4.88	15.68
5	59.67	.91	1.51	.70	3.12	62.79	4.97	12.56
10	59.67	1.17	1.51	.47	3.15	62.82	5.01	6.28
15	59.67	1.43	1.51	.23	3.17	62.84	5.04	4.19
20	59.67	1.69	1.51	—	3.20	62.87	5.09	3.14
30	59.67	2.21	1.42	—	3.63	63.30	5.73	2.11
60	59.67	3.62	1.34	—	4.96	64.63	7.67	1.08
143	59.67	8.01	1.37	—	9.38	69.05	13.58	0.48

TABLE 3

Analysis of Productive and Nonproductive Work in the Assembly of a TV Chassis on Powered Conveyor Lines for Various Assembly Cycles (Company 2)

(Time in Minutes)

Number of Stations or Operators *1*	Productive Work Content Time *2*	Nonproductive Work Content Time					Total Work Content Time *8*	% Nonproductive of Total Time *9*	Cycle Time *10*
		Product Handling *3*	Tool Handling *4*	Return to Position *5*	Extra Component Allowance *6*	Total Nonproductive Work Content Time *7*			
LINE 1									
26	51.86	.82	.94	.21	—	1.97	53.83	3.66	2.07
50	50.55	.91	.88	.41	—	2.20	52.75	4.17	1.06
LINE 2									
25	49.22	.86	.95	.19	—	2.00	51.22	3.90	2.05
33	50.06	.89	.90	.27	—	2.06	52.12	3.95	1.58
50	49.31	.95	.84	.40	—	2.19	51.50	4.25	1.03

tive time induced by the extended division of labor is not an important cost factor. In this regard one cycle length is about as good as another.

It seems well at this point to warn against a possible incorrect inference from the data of Table 1. The total work content time (Column 8) is shown to be 62.57 minutes per chassis if a single operator does all the work, against a minimum value of 62.08 minutes if assembly is performed by a line of 20 operators. Why then set up a line and incur the problems of line operation rather than have multiple one-man stations? The answer is that the data of Table 1 assume all other factors are held constant, an abstraction from reality and an impossible situation. Nonproductive is only one factor in determining the optimum extent to which the task should be broken down. The best division is determined, to a first approximation, by minimizing the total of four cost factors:

1. Learning cost.
2. Nonproductive work cost.
3. Balance-delay cost.
4. Quality-loss cost.

One cannot, therefore, make correct inferences about the best division of work from a study of nonproductive time only (1).

Table 2 shows the same analysis for nonpowered conveyor lines. Return-to-position time (Column *5* of Table 1) is not included in Table 2 for reasons previously explained.

In Figure 2 nonproductive time as a percent of total time, Column *8*, is plotted as a function of cycle time, Column *9*, for the case of nonpowered conveyors. It shows that the cost of nonproductive work moves sharply upward for cycle times less than two minutes, reaching about 13 percent of assembly time at a one-half minute cycle. For cycle times of three minutes and over, nonproductive time remains virtually constant at about 4.8 percent. For cycle times of less than two minutes, therefore, nonproductive work is an important cost factor for work done on nonpowered conveyors. Within the range of possible cycle times shorter than two minutes, say to a minimum cycle of about one-third of a minute, the cost of nonproductive work rises to about 15 percent of assembly labor cost.

RESULTS: COMPANY 2

The Company 2 data are not as extensive as the Company 1 data. Information was available for two very similar chassis assemblies performed at a total of five different cycle times on powered conveyor lines. No data were available for nonpowered conveyor lines. The analysis is shown in Table 3. The points taken from Columns *9* and *10* of Table 3 are plotted on the expanded portion in the upper right hand corner of Figure 1. The points for Company 2 are shown as *X*'s. All five points fall close to the curve drawn for Company 1. This is considered a verification of Figure 1 for cycle times ranging from one to two minutes.

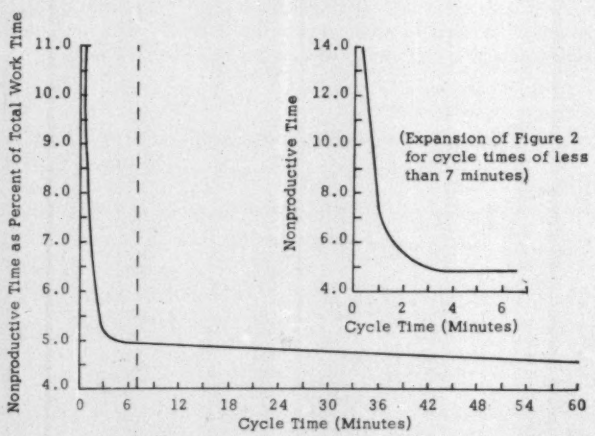

FIGURE 2. Nonproductive Time as Percent of Total Work Time for Various Assembly Cycle Lengths on Nonpowered Conveyor Lines.

CONCLUSIONS

In determining the optimum extent to which assembly work should be broken down several cost factors are pertinent. One of these is the cost of nonproductive work induced by the division of labor. This takes the form of handling time and operator movement to and from the work position. It is conceivable that, as the division of work proceeds and the individual assignments get smaller and smaller, a point is reached at which the cost of nonproductive work exceeds the savings resulting from the division of labor.

This study shows that for powered conveyor work in the consumer electronics industry such a cross-over point is not reached within the range of feasible cycle times. That is, the continued division of work is blocked by the existence of irreducible work elements (at about the point of one-third of a minute) before the cost of nonproductive work turns sharply upward. For powered conveyor lines the cost of nonproductive work varies little within the range of all possible cycle times.

For nonpowered conveyor lines, on the other hand, the division of work beneath the point of a two-minute cycle results in considerable cost of nonproductive work. This can reach a maximum of about 15 percent of direct labor cost for very short cycles. In practice it is possible to extend the division of work to the point where excessive added cost results.

Although this study was conducted in the special situation of television chassis assembly in the consumer electronics industry, it is thought to have general meaning for all seated progressive assembly work performed directly on the conveyor. The four classes of nonproductive work: product handling, tool handling, return-to-position time, and station-size allowance are common to this kind of assembly work, and their behavior in this study is thought to be typical of their behavior in general.

REFERENCE

(1) Kilbridge, M., and Wester, L., "The Assembly Line Problem," *Proceedings of the Second International Conference on Operational Research*, September, 1960.

A Game-Information Theoretic Decision Model

by **R. W. LLEWELLYN**

Professor of Industrial Engineering, North Carolina State College

A DECISION model is presented in this article which is derived from an information model proposed by Ackoff (1). The eventual decision is made by playing a game against nature. Incorporated into the model is a criterion by which can be judged the degree of orientation of the decision maker in his environment as compared with other decision makers in comparable environments.

ACKOFF'S THEORY

Information theory as originally developed by Claude Shannon and previously summarized for readers of this *Journal* (3) has been found to be relatively impotent as a technique in the field of management control or decision making. In an effort to develop something of value for workers in our field, Ackoff constructed a behavioristic model of communications. We will review only those portions of Ackoff's paper which provide the basis for the present work.

Ackoff discussed an entity I in an environment N which has m potential courses of action, each denoted by C_i, $i = 1, 2, \cdots, m$. With each C_i is associated a probability

(P_i) that I will elect to take the ith course of action. The C_i are exclusive and the whole set $\{C_i\}$ of courses of action is exhaustive, so that we have the conditions

$$0 \leq P_i \leq 1, \qquad i = 1, 2, \cdots, n$$

$$\sum_{i=1}^{n} P_i = 1$$

The courses of action available to I will ultimately lead to a set of n outcomes $\{0_j\}$. Associated with each outcome 0_j there is a value v_j. Each of these v_j is unrestricted as to size and sign. To obtain a measure from one situation to another, Ackoff defines a relative value V_j for each outcome 0_j by

$$V_j = \frac{v_j}{\sum_{j=1}^{n} v_j} \text{ if all } v_j \text{ are nonnegative and} \qquad \text{Eq. 2.}$$

$$V_j = \frac{v_j}{\sum_{j=1}^{n} |v_j|} \text{ if the } v_j \text{ are not all nonnegative.} \qquad \text{Eq. 3.}$$

If all v_j are nonnegative, we have

$$0 \leq V_j \leq 1$$

$$\sum_{j=1}^{n} V_j = 1 \qquad \text{Eq. 4.}$$

If some of the v_j are negative, we have

$$0 \leq |V_j| \leq 1$$

$$\sum_{j=1}^{n} |V_j| = 1 \qquad \text{Eq. 5.}$$

Finally, associated with each course of action C_i and each outcome 0_j there is a probability E_{ij} that if the former is selected, the latter will occur. The only restriction placed on the E_{ij} by Ackoff is

$$0 \leq E_{ij} \leq 1, \qquad \text{Eq. 6.}$$

since each E_{ij} is a probability.

With this set of definitions of the factors in I's environment, Ackoff suggested that a communication could then:

1. Inform (or misinform) if it caused I to change the probabilities of selecting each of the available causes of action.
2. Instruct (or misinstruct) if it increased or decreased the likelihood that specific outcomes would follow from the selection of one of the courses of action available.
3. Increase (or decrease) motivation by changing the relative values of the outcomes.

Ackoff then suggested that the present state of I's environment has a value $V(S)$ which is a function of the P_i, the E_{ij} and the V_j. In fact he suggested the expectation formula

$$V(S) = \sum_{i=1}^{m} \sum_{j=1}^{n} P_i E_{ij} V_j \qquad \text{Eq. 7.}$$

Eq. 7. is equivalent to

$$V(S) = PEV, \qquad \text{Eq. 8.}$$

where P is the row vector (P_i), E is the matrix (E_{ij}) and V is the column vector (V_j).

Thus, the effect of a communication can be determined by calculating $V(S)$ by Eq. 7. or Eq. 8. before an after receipt of the message. However, we wish to make a different application of Ackoff's notions.

THE MODEL

The first of two modifications we make is to force the values of all of the outcomes to be nonnegative. If the original values of some of them are negative, then we will modify all of them by

$$v_j' = v_j + c, \qquad \text{Eq. 9.}$$

where c equals the smallest v_j.

Thus, one of the v_j' will be equal to zero. This modification forces all V_j' to be nonnegative also. In the sequel we will assume that the modification of Eq. 9. has been performed, if necessary, and will not use the primes on the v_j or V_j.

The second modification is to require that the 0_j be exclusive and that the set of outcomes $\{0_j\}$ be exhaustive. In other words, at least one, but not more than one outcome will result from the selection of one C_i in any given instance. This requirement is met, mathematically, by demanding that

$$\sum_{j=1}^{n} E_{ij} = 1 \qquad \text{for each } i. \qquad \text{Eq. 10.}$$

Or, in simpler terms, E must be a stochastic matrix.

We then can interpret more precisely the status of I in his environment.

Definition 1. I is said to be *perfectly oriented* with respect to his environment if $V(S) = PEV = 1$. This can happen in several ways, in say, a 3×3 system. An example is:

$$P = (1, 0, 0)$$

$$E = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

So that

$$V = \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix}$$

$$PEV = (1, 0, 0) \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \\ 0 \end{pmatrix} = 1$$

For this result to occur, one P_i must equal 1, with all

other P_i equal to zero; one V_j must equal 1, with all other V_j equal to zero; one E_{ij} must equal 1, with all other E_{ij} on that row equal to zero. Furthermore the units P_i, V_j and E_{ij} must be correctly aligned if PEV is to equal 1.

A person who is perfectly oriented with respect to his environment is one who knows which outcome is most desirable, knows the best course of action to use and knows how to carry it out so that the desired outcome will occur.

Definition 2. A person is *completely disoriented* with respect to his environment if $PEV=0$. If $P=(0, 1, 0)$ but E and V are as in the above example, then $PEV=0$. In this case, the course of action chosen by I leads to an outcome other than the one desired by him; he knows what he wants but is completely misinformed as to how it may be attained. There are many ways in which a person may be completely disoriented with respect to his environment.

Definition 3. I is *indifferent* with respect to his environment if

$$PEV = \frac{1}{n}.$$

In a 3×4 system, we might have[1]

$$PEV = (1/3, 1/3, 1/3) \begin{pmatrix} 1/4 & 1/4 & 1/4 & 1/4 \\ 1/4 & 1/4 & 1/4 & 1/4 \\ 1/4 & 1/4 & 1/4 & 1/4 \end{pmatrix} \begin{pmatrix} 1/4 \\ 1/4 \\ 1/4 \\ 1/4 \end{pmatrix} = 1/4$$

A person indifferent to his environment has no preferences among the outcomes, has no basis for selecting a course of action or any ability to predict the outcome resulting from a particular course of action.

From a study of the foregoing definitions and illustrations it is obvious that if I seeks to maximize the degree of his orientation, then the P_i must be dependent on the E_{ij} and the V_j. A communication can give more accurate information concerning the relative values of the potential outcomes and can supplement existing knowledge concerning the probable outcomes resulting from the courses of action available. But it cannot, independent of the other two considerations, give rational information concerning the selection of courses of action. Consider the better at the racetrack. He decides on which horse to place his bet according to his estimate of the ability of each horse and on the probable odds at track time. If he discards all of this reasoning and acts on a "tip" received from an acquaintance, he is acting in an irrational manner and outside the class of decision situations of interest to us here.

If we then consider that I is to make a decision on a course of action to use at some instant, one of the P_i becomes 1 at that instant and all other P_i become zero. The manner in which we suggest making the decision (that is, which P_i will become 1), is by playing a game against nature. The vector V, which has the properties of a probability vector, we will take to be the strategy to be played by nature. Nature, however, is not intelligent and this strategy is therefore not necessarily optimal for her.

The decision rule we suggest for this game is to select that row (P_i) for which EV is a maximum. For row 1, this would be

$$\sum_{j=1}^{n} E_{1j}V_j \qquad \text{Eq. 11.}$$

and is an expectation. Our decision rule, then, is to find

$$V(S) = \max_i \sum_{j=1}^{n} E_{1j}V_j. \qquad \text{Eq. 12.}$$

We show a numerical example to make this clear. Suppose that we have

$$E = \begin{pmatrix} 1/2 & 1/4 & 1/4 \\ 1/4 & 1/2 & 1/4 \\ 1/3 & 1/3 & 1/3 \end{pmatrix} \quad \text{and} \quad V = \begin{pmatrix} 1/3 \\ 1/2 \\ 1/6 \end{pmatrix}$$

Then if I selects row 1,

$$V(S) = (1/2, 1/4, 1/4) \begin{pmatrix} 1/3 \\ 1/2 \\ 1/6 \end{pmatrix} = 1/3.$$

For row 2, $V(S)=3/8$ and for row 3, $V(S)=1/3$. By Eq. 12. we would let $P_2=1$, or $P=(0, 1, 0)$.

The value of I's orientation with respect to his environment is then 3/8 as compared to 1/3 for a person indifferent to his environment. Thus, even when utilizing the information contained in E and V to make the most intelligent decision concerning P that can be made under the expectation criterion, I is poorly oriented in his environment in this example.

AN EXAMPLE

The following is a nonnumerical example of the application of this model. I is an executive interested in making a decision pertinent to expanding his firm's production capacity of a given product. The courses of action are such alternates as expanding an existing plant, replacing existing equipment with more productive equipment, etc. The outcomes are net returns of the total production of this product over, say, the next ten years, divided into dollar ranges. For example, 0_1 could represent a loss range from 1 to 2 million dollars, 0_2 a loss range from zero to one million dollars, 0_3 a profit range from 0 to one million dollars, etc.

In practical situations of this type, the firm is moving into a future during which the potential sales can only be estimated on a probability basis. In setting up the problem, the firm's market analysts would prepare a series of estimates of sales with a probability assigned to each. Thus, one forecast might be no increase in sales, with a

[1] If $P=$ (1, 0, 0) and E and V are as given, PEV still equals ¼.

probability of 0.05. A second might call for 2% increase in sales per year with a probability of 0.06, etc.

Each alternative would then be evaluated over every one of the forecasts and the dollar net income calculated. The calculations would include expected revenue and expected costs, including the usual interest charges on capital investments, and would terminate with each outcome being assinged to its appropriate outcome range (0_j). The E matrix would then be constructed by accounting for the probabilities given for the forecasts. For example, if C_1, evaluated over the first forecast, which has a probability of 0.05, results in a dollar net income within 0_1, then E_{11} is set equal to 0.05. If C_1, evaluated over the second forecast, which has a probability of 0.06, results in 0_1 also, then E_{11} is increased to 0.11. By evaluating all courses of action over all forecasts, the E matrix can be constructed for all courses of action and all outcomes.

Having the E matrix and the V column vector, the course of action to take can then be determined from Eq. 12. The actual dollar expectation can be determined by reverting to the basic calculations used in evaluating that course of action over the various forecasts and determining the dollar expectation over that row. The orientation factor of I will be the maximum result from the application of Eq. 12.

DISCUSSION

We wish to discuss several points concerning this model which will perhaps coincide with questions in the minds of the reader.

1. There are other criteria for playing games against nature. One is to play the row which involves the maximum of the minimum potential gains. Another is to play the row which involves the maximum of the maximum possible gains. Several more complicated criteria have also been proposed (2). But for a management which will be making many similar decisions over an extended period of time, the maximum expectation appears to be most reasonable, particularly if nature's strategy is known. It was favored in this model because it fits Ackoff's theory and is consistent with the calculation of I's orientation factor.

2. One might question the validity of a model in which either the E matrix or the V column vector or both are established by estimates. Can such a model be valid if based on such approximate data? The answer, of course, is that the answer can be no better than the original estimates. The value of the model is that it prevents the answer from being much *worse* than the original estimates.

Consider the executive who makes a decision and then orders its implementation. It may not be a perfect decision, but, on the average, the eventual results will be inferior to the extent that the implementation is not performed as directed. Thus, if his order is a verbal one and is altered slightly everytime it is transferred down the administrative line, the probability of effective and efficient action becomes low, indeed. Such distortion in the "communication line" is called *noise* by the communications engineer and the executive usually prevents noise by reducing his order to writing, hoping that all junior personnel will read this order and thus prevent noise from becoming a factor.

In the engineering economy example, an executive working without the model would intuititively evaluate all of the information in the E matrix and V vector, although it would probably not be presented to him in such an orderly fashion. The inability of any human intellect to simultaneously evaluate many conflicting and complex factors introduces noise into the decision process. Our model, in common with many other mathematical models, seeks to eliminate this noise and preserve what validity is contained in the original estimates.

3. The footnote on the example after *Definition 3* noted that P can be either (1/3, 1/3, 1/3) or (1, 0, 0) without changing the value of PEV. Other P vectors that will not change the result are (0, 0, 1) and (1/2, 1/2, 0). The general principle is that if in applying Eq.12., two or more rows are involved in a tie, the P vector can be formed by assigning the value of 1 to one of the P_i or appropriate equal values can be applied in any combination of the tied rows. In the example after *Definition 3*, all three rows are involved in the tie; thus the term indifference. If only two rows had been involved, it would have represented a more restricted degree of indifference.

4. Even under an intelligent decision procedure, the orientation factor can be less than that signifying indifference. Consider

$$E = \begin{pmatrix} .14 & .85 & .01 \\ .90 & .08 & .02 \\ 1 & 0 & 0 \end{pmatrix} \quad \text{and} \quad V = \begin{pmatrix} .02 \\ .03 \\ .95 \end{pmatrix}$$

Then, by the rule,

$$P = (0, 1, 0)$$

and $PEV = .0394$.

Thus, indifference is not by any means the most unfavorable degree of orientation that a decision maker may experience. But in spite of the fact of this example, it is reasonable to require that no degree of orientation be acceptable unless it exceeds that of indifference by a considerable margin. Lacking this, the decision maker should determine a method of improving his orientation rather than implement any decision made. This additional study of the problem may very well include a search for additional courses of action.

SUMMARY AND CONCLUSIONS

1. A decision making model is developed which permits a logical selection of a course of action given the relative values of the potential outcomes and the probabilities that specific courses of action will result in specific outcomes.

2. A measure of the degree of orientation to his environment that is processed by a decision maker at the time of his decision is given as a by-product of the model.

3. The model is applicable to a wide variety of decision processes, and is especially applicable to engineering economy models.

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Profit Maximization and Industrial Engineering

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THIS PRESENTATION deals with the concept of profit maximization as an organizational goal and the effects of such a concept upon the practice of Industrial Engineering. First, an attempt is made to summarize contemporary thought in managerial economic literature with particular regard for the substantive nature of the profit goal and the degree of compatibility of managerial behavior with such a goal. This is followed by a discussion of implications for Industrial Engineering which managerial behavior patterns present. Certain specific effects upon selected Industrial Engineering activities are analyzed and discussed.

PROFIT MAXIMIZATION GOAL

Business executives often are pictured by Industrial Engineers as the culmination of the "economic man."[1] They are viewed as routinely conducting a set of dollar calculations prior to every decision, judging money equivalents for intangibles when the occasion requires, and always attempting to minimize costs and maximize profits.

Much has been said in economic literature concerning the controlling objectives of entrepreneurs and business managers. Virtually all such references deal with factors which presumably impede profit maximization. The objective of this article is to argue that the principles and practices of Industrial Engineering should not necessarily premise cost minimization nor profit maximization as primary management criteria.

ORIGIN OF PROFIT MAXIMIZATION

During the eighteenth century Adam Smith laid the theoretical foundations for modern capitalism. Smith assumed that there was a certain natural order to which economic processes tended to conform. This conformity was such that, after certain artificial restrictions had been removed, labor, capital, and natural resources would seek their most profitable and efficient combinations. If the entrepreneur be rational in directing these factor combinations, then profit maximization is achieved. As an inherent characteristic of this economic process, classical economists assumed the existence of an "economic man." This existence was, at least partially, caused by the hypothesis of Jeremy Bentham that all men are alike in loving pleasure, hating pain, and being selfish.

There is reason to believe that siginficant evolutionary changes in economic philosophy have occurred such that the inclusion of certain nonmonetary factors give a better explanation of man's behavior in economic activities.

PROFIT MAXIMIZATION FUNCTIONS

Under conditions in which business firms seek to maximize profits, there is probably no universal agreement, perhaps a lack of knowledge, as to the function which the entrepreneur should maximize. Four logical possibilities, as described by the Lutzes (17, pp. 16-48) for this profit maximization function, are listed. In these R = present value of the future gross revenue, C = present value of present and future costs of investment, p_a = internal rate of return, and k = rate of return on the entrepreneur's own capital:

1. The difference, $R - C$, should be maximized.
2. The ratio, R/C, should be maximized.
3. The internal rate of return, p_a, on total capital should be maximized.
4. The rate of return on the entrepreneur's own capital (equal to or less than total capital), k, should be maximized.

All four of these criteria have been used in the literature. Since different criterion functions do not all result in unique actions, the importance of the selection of a criterion function cannot be overestimated—particularly in the light of the present emphasis upon the use of some of the mathematical techniques of operations research in Industrial Engineering activities. Each of the criteria may induce different actions by the entrepreneur when he is supposedly maximizing his profits.

If economists were unanimous concerning the defi-

[1] The "economic man" is defined to be an individual who constantly tries to pursue his economic self-interest.

nition of profit, it might be possible to select one of the criterion possibilities mentioned, or perhaps some other criterion, as the function which must be maximized when profits are to be maximized. Since economists do not agree on the nature of profit, complexities arise as to what is meant by maximizing profit. It can be concluded that an arbitrary policy must be made regarding the criterion function if profit maximization is to be attempted; and that if some other criterion function were selected for maximizing profit, the two resulting decisions would not necessarily be identical.

ENTREPRENEURS

There are certain conditions under which an entrepreneur does not attempt to maximize his profits. The simplest example of nonprofit maximizing behavior of an entrepreneur is one in which he consumes part of his time in leisure activities in lieu of working continuously. Often it is considered self-evident that the rational behavior of an entrepreneur includes an attempt at profit maximization, which is equivalent to maximizing satisfactions. However, only under special conditions will the maximizing of profits and the maximizing of satisfactions produce identical results.

Scitovsky (24, p. 356) contends that a businessman's entrepreneurial activity will remain unaffected by a rise in income, for the entrepreneur considers this income as a symbol of his success in life, which with many persons may be virtually insatiable.[2] If the entrepreneur seeks money as a token of his success in life and his desire for success is insatiable, then it is logical to say that this entrepreneur can maximize his satisfactions and his profits simultaneously. However, when the entrepreneur seeks money only to improve his standard of living to a desired level, his satisfactions and profits are not simultaneously maximized.

Reder (19, pp. 455-457) considers a restraint to the maximization of profits which has applicability to the firm controlled by an owner-entrepreneur. The decision process of the entrepreneur is to attempt to maximize profits provided there is no danger in losing control of the firm. Reder shows that when the desire to retain control of the firm is powerful, the growth rate of the firm will be somewhat less than that which is required in order to produce maximum potential profits. Only if an entrepreneur has an enormous amount of capital will he be free from concern of losing control. When the entrepreneur is worried about losing control of the firm, he can be assured of retaining control by reducing the firm's assets somewhat and paying off certain pressing obligations—an example of nonprofit maximizing behavior.

The unscrupulous entrepreneur may attempt to show the best possible return on his capital in an attempt to deceive fellow investors. This deception can be practiced by undermaintaining equipment or by using extremely long depreciation write-off periods, to mention but two methods.

OLIGOPOLY

The market condition of oligopoly is considered since a substantial volume of business is conducted under this type of market atmosphere. The remarks made here are equally appropriate for monopoly conditions.

In a study by Kaplan (15) of companies involved in non-pure competition, the following classifications were referred to frequently as company objectives:[3]

1. Target return on investment.
2. Stabilization of price and margin.
3. Maintenance or improvement in market position.
4. Product differentiation.

Criticisms have been made concerning these four objectives, such as, these goals are merely short-range goals, the long-range goal is that of profit maximization. In order for the concept of profit maximization to apply, it must be broadened to such an extent that it becomes subjective in nature and of little use in making objective decisions.

During the past 100 years the control of United States companies and corporations has changed from that of the owner-manager to that of the professional manager. It was in the 1930's that economists[4] described market situations (imperfect competition and monopolistic competition) which differ from those of pure competition. Only recently has a theory of oligopoly emerged.[5] This theory, for the most part, lacks the determinateness of pure competition or of monopolistic competition.

Reder (19, pp. 453-454) contends that this change in market conditions away from keen competition and toward a less competitive condition has caused a departure from the principle of profit maximization. As a result of "market" forces, any deviation from profit maximization in firms under keen competition would be quickly corrected by the natural forces of competition. However, upon considering a market situation in which few firms exist and the entry into the field is restricted, it is commonplace for these firms to adapt themselves to new

[2] This line of reasoning is compatible with that of Thorstein Veblen's belief that the businessman is interested only in pecuniary gain (16, p. 356).

[3] The specific objective of Kaplan's study was concerned with pricing policies; however, he mentioned that these same policies were referred to regarding the company policies in production, investment, and other aspects of company policy. Kaplan concluded that, although profit maximization is not achieved in the conventional sense, profit-making was a guiding principle in all the companies in his sample (15, pp. 128-130).

[4] Joan Robinson's *Economics of Imperfect Competition* (21) and Edward Chamberlin's *Theory of Monopolistic Competition* (4) both appeared in 1933.

[5] Oligopoly is characterized by a small number of firms in an industry where entry into this industry is highly restrictive; product differentiation may or may not exist.

situations at their own convenience without the fear of intense competition; hence, the impelling force to attempt profit maximization has disappeared since survival is no longer a basic problem in oligopolies.

Reder (19, p. 453) cites an example of a company which had the advantage of a superior market position; and although it showed a satisfactory return, considerable inefficiency was tolerated. However, when losses began to occur, attempts were made to reduce costs and remove certain inefficiencies. This practice of tolerating inefficiencies as long as a satisfactory return is obtained is probably a characteristic of oligopoly. The results of Reder's survey imply that the companies were not presently attempting to maximize profits.

Profit maximization is a survival condition in perfect competition (18, p. 207). The force of profit maximization is weaker in the case of imperfect competition since the businessman is expected to have dollar margins with which to work and with which to satisfy desires other than the desire for profit. These desires which lead to nonprofit maximizing behavior are classified into the following categories:

1. Desire to produce below the profit maximizing level. The desire for leisure exemplifies this case.
2. Desire to produce above the profit maximizing level. The desire for owning a large firm and the desire for prestige are examples of this case.
3. Desire not to change the prevailing level. This case may be brought about by resistance to change, or, "don't rock the boat."

Since there have been satisfactory dollar margins in recent years in the United States economy, desires other than the pure profit desire have been satisfied; therefore, these behavior classifications appear reasonable.

Much of the reasoning forming a basis for a private enterprise economic system has been predicated upon the assumption that business decisions are made by profit motivated entrepreneurs. Although it may appear reasonable on the surface to make the assumption that there is little or no difference between the actions of entrepreneurs and the actions of managers, there is some doubt as to the operational reasonableness of this assumption. Since the entrepreneur owns all or most of the stock in a firm, he personally will rise or fall with the results of his business actions; such a strong tie does not exist with the professional manager who owns little or none of the stock in his firm.

Gordon (10, p. 321) wonders whether or not managers in the middle echelons of management who make most of the day-to-day operating decisions are as willing to make exceptional decisions as would be the owner-entrepreneur. Executives of large corporations must spend most of their time attempting to coordinate the decisions made by subordinates, having little additional time to determine whether or not profits are being maximized. Decisions regarding various proposals usually tend to be made more in consideration of general solvency and liquidity than for the consideration of the particular merits of each proposal as regards its efficiency and profitability. The top executive has the responsibility of receiving the recommendations of his subordinate executives and resolving their internal inconsistencies and conflicts in order to make a firm-wide decision. Often the objectives of the several functional areas of the firm are in conflict. The top executive is compelled to make compromise decisions, which do not necessarily reflect profit maximization. Gordon (10, p. 324) also mentions "scientific caution" as a typical attribute of professional executives. This trait prevails by virtue of the fact that they do not share directly in the profits resulting from successful chance activities, while their positions may be in jeopardy if a failure occurs. Accordingly, they are prone to act conservatively as long as a reasonable return is being realized.

There are other examples of nonprofit maximization behavior in the large corporation. Reder mentions (19, p. 452) the notion of resistance to change as being a factor in nonprofit maximization activities. Supervisors will at times fail to introduce a change into the working habits of their subordinates, rationalizing that the introduction of a change at this time would seriously affect the motivation and morale of their men. This effect may occur also from the other direction. Subordinate personnel may be reluctant to suggest changes which their superiors might have had a part in establishing out of fear that a suggested change will be taken by the boss as direct criticism.

In the lower echelons of management, particularly at the foreman level, it is quite common for company activities to be at divergence with the presumed goal of maximum profits. Foremen have been known to suggest informally to their men that each man reduce his output in order to avoid layoffs or reductions in piece rates. It is not unusual that a supervisor will resist reducing the number of personnel in his charge for at least two reasons:

1. He will appear to have less prestige.
2. He may then need to exert greater supervisory effort in order to accomplish the job.

An interesting question arises as to whether the dollar margin, previously referred to, results from or causes this nonprofit maximizing behavior.

The worker may oppose increased productivity because he feels that the company is presently making too much profit (28, p. 50). Regardless of how irrational this reasoning may appear to the management of the company, workers often do feel that they are not getting their proper share.

All echelons in the modern (oligopoly) firm have tendencies to exhibit behavior which is inconsistent with profit maximization. If it is possible to conceive of the summation of the nonprofit maximizing behavior of the individuals in each echelon of the firm over all echelons, there would be only a slight probability that

the aggregate behavior of a firm is directed toward profit maximization.

SOME USEFUL ALTERNATIVE GOALS

The apparent inadequacies of the principle of profit maximization as an explanation of corporate behavior have been implied from the discussions in preceding paragraphs. An attempt will be made now to salvage some concepts which may be useful as either a substitute for or an addition to the profit maximization principle as an explanation of the oligopoly objective.

The goal of satisfactory profits appears to be consistent with the behavior, described by Reder, that inefficiencies are tolerated as long as a satisfactory return results. Due (8, p. 43) states that there are some instances in which the satisfactory profits' goal is the dominant goal. Due also remarks that this goal may result coincidentally in maximum profits. He implicitly assumes long-run profits to be the sum of the expected profits in each of the future years discounted back to the present, since the market is not being exploited and the entrance of new firms is discouraged. By obtaining only a satisfactory profit rather than maximizing profits, the possibility of government control is somewhat reduced.

The goal of satisfactory profits is equivalent to the goal of a specified target return on investment. Kaplan (15, p. 130) found that many of the companies in his sample stressed a target return on investment, in contrast to profit maximization. Unit prices in some cases were determined by using a mark-up such that this target return, as specified by management, would be achieved. In other cases the mark-up was based upon a combination of factors: competitive prices, value of product to consumer, and desire to obtain the specified target return.

The goal of satisfactory profits does apparently explain the behavior of a large number of United States corporations. A degree of quantitativeness is added to the profit function where this goal is applicable, since satisfactory profits may be defined in advance to be a specific rate of return on investment. With this goal, as with other goals, more specific than profit maximization, it is easier to ascertain the steps necessary to be undertaken in order to achieve this more specific goal.

The goal of secure profits is predicated upon a desire which is of the same magnitude as the desire to maximize profits. Rothschild (22, p. 450) hypothesizes that this motive has not occurred overnight, that economists have long been aware of the desire by entrepreneurs and businessmen for secure profits. Previously it was thought that the desire for secure profits could be included with the concept of long-range profits, since it was postulated that by striving for secure profits, long-range profits would be maximized. The desire for secure profits results from the uncertainty of the future. The future appears more certain when the risks that accompany short-range profit maximization are not undertaken. If businessmen maximize long-range profits, knowledge is required of the demand and cost schedules at a future time. Obviously, reliable knowledge of the future does not exist. Consequently, the goal of secure profits is not equivalent to long-range profit maximization. It can be said, however, that the businessman may attempt to maximize his short-range profits provided he has security in obtaining a certain minimum profit.

Although there are certain cases in which the desire for both profit maximization and security maximization coincide, there are conditions, described by Rothschild (22, pp. 452, 459) in which the two motives lead to conflicting behavior, as follows:

1. Profit maximization may require price fluctuation, while security maximization may require price stability.
2. Profit maximization may require optimum size firms, while security maximization may require over-sized firms.
3. Profit maximization may require that funds be invested where the expected return is the greatest even if the investment is external to the company, while security maximization may require investment within the firm regardless of external investment opportunities.

Another example of the security motive, as mentioned by Rothschild (22), is the desire to improve or expand a firm's share of the market. Several of the companies in Kaplan's sample (15, p. 157) revealed a policy of attempting to improve or maintain their market position. Kaplan states that usually a market share policy is incompatible with a target return policy.

Profit maximizaton is subject to certain *financial ratio constraints*. Foulke (9) lists certain financial ratios which experience has shown to be indicators of business health. It would follow then that the organization using a policy of profit maximization subject to certain financial ratio constraints would be in a better position continuously to make satisfactory profits than would be an organization which would allow its financial structure to become disturbed as a result of heavy risk, high potential-profit ventures. One disadvantage of such a procedure is the difficulty of obtaining proper ratios.

Gordon (10, pp. 327-328) suggests other goals which the business executive may wish to follow after a certain profit that is necessary to keep the directors and stockholders content has been obtained. These goals appear to be the desire for personal position and power, the desire to see the firm larger and more powerful, compassion for various social groups such as workers and consumers, protection of the firm's position in the industry, maintenance of a liquid position, and the desire for secure profits. These goals are often referred to as strategic considerations which when taken into consideration will, presumably, enlarge profits in the long run. Gordon states that this approach to enlarging profits may be realistic in certain cases, but that this emphasis relates only indirectly to profit maximization over any

specific period. And further, he states that these nonprofit criteria may become accepted inadvertently by executives as an easy way to obtain long-range profit maximization.

The managements of today's large corporations do not take advantage of all profit opportunities. Several companies have attempted to differentiate their product by qualities that could be uniquely associated with the name of the company. This goal of product differentiation will not necessarily lead to maximum profits in the short run because of the heavy marketing expense; however, the strong differentiation may more than pay for the marketing expense in the long run. Although it is not known that such a goal of product differentiation will produce profit maximization, the probability of this phenomenon's occurring is remote because of the many exogenous factors involved.

Drucker (7, pp. 291-292) considers profit as only one of several objectives that management should have. He states that to emphasize profits alone will tend to endanger the survival of the business. Many postponable investments, such as research, sales promotion, equipment replacement, and others will be harmed by considering profits alone. The following eight key objectives are listed: market standing, innovation, productivity, physical and financial resources, profitability, manager performance and development, worker performance and attitude, and public responsibility.

CONCLUSIONS REGARDING PROFIT MAXIMIZATION

The belief that entrepreneurs and businessmen strive for profit maximization received its greatest momentum from the early classical economists. The profit maximization belief may have been perpetuated by some economists, not so much because of complete agreement with it, but rather in the realization that suitable alternative concepts of behavior are difficult to explain or manipulate. Although a quantitative function which describes profits has not received agreement from all economists, uses of different functions have been helpful in describing the actions necessary to maximize a specific profit function.

Entrepreneurs do not always attempt to maximize profits; objectives such as the maximizing of satisfactions and the retention of control of the firm conflict with attempts toward maximizing profits. Professional managers, predominant in industry today, do not hold to the same beliefs and do not have the same motivations as the entrepreneur or the owner-manager. Economists and psychologists have noted that there exists nonprofit maximization motives and behavior patterns of individuals in all echelons of a modern organization.

Examples of various tenable hypotheses that offer alternative objectives to that of profit maximization are the desire to obtain a target return on investment, desire to maintain or increase market position, the desire to maintain stability of prices or employment, and the desire for product differentiation. Although the objective of making a profit appears to be unanimous with many large corporations, the concept of profit maximization does not appear to be characteristic of these corporations.

We conclude that in the United States economy, maximum profits are not frequently attained and that there are few attempts to attain this objective.

EFFECTS UPON SELECTED INDUSTRIAL ENGINEERING ACTIVITIES

In Industrial Engineering activities there appears to be an underlying implicit assumption that all *rational* decisions are directed toward one objective, profit maximization. In a preceding part of this presentation several conditions were considered in which the results of apparently rational behavior did not lead to profit maximization. The theme here is concentrated upon Industrial Engineering criteria and how they might be altered for desired objectives.

METHODS IMPROVEMENT

Methods improvement proposals which require small expenditures or minor changes usually can be approved by the foreman of the department. Some proposals may be disapproved by the foreman because he regards such suggestions by "outsiders" as direct criticism of his own ability, regardless of the merits of the proposals. Rejection may come simply because the proposal changes the procedure of performing the job. Proposals have been known to be rejected because the methods engineer did not communicate his ideas properly. Profit considerations are quite unlikely in such cases.

Methods improvements which require substantial expenditures usually must be approved by an executive committee composed of members from various departments within the company (3, pp. 22, 27-28). Since it must approve investment requests throughout the company, this committee supposedly is cognizant of needs in the various departments. However, it is likely that at least one member is more persuasive than the other members; therefore, some departments will obtain approval for investments when these investments are not the most profitable from an overall company standpoint. Also, some of the more profitable proposals may be rejected.

Grant (11, p. 466) states that proper acceptance of investment proposals should be based initially on the expected rate of return; intangible considerations are used to modify the rate of return criterion. When there are many proposed investments and there is an insufficient supply of funds to undertake all of the worthy proposals, nonprofit maximizing behavior may obtain because of nonprofit characteristics of intangible considerations. Management may pride itself in operating

and maintaining the most modern buildings and equipment, with profitability considerations given secondary importance.

Another commonly used, but nonprofit maximizing, criterion for accepting proposals is the requirement that all acceptable proposals must pay for themselves in a specified period of time. Grant (11, pp. 466-467) believes that the payout period is not a proper criterion because it fails to give weight to the difference in long-term consequences of different investment proposals. Barnes (1, p. 312) uses payout period as a measure supplementary to estimated savings per year.

Similarly, as in approving investment proposals, the proposals for adding new products to the product line of an organization are not accepted on the basis of profitability alone (6, p. 367). Other factors which are of considerable importance in evaluating proposals for new products are the compatibility of the proposed product to the existing line of products and the ease by which the new product can be integrated into the mechanisms of production and distribution.

A choice between alternatives is based logically upon a test against proper criteria, either *monetary* or *nonmonetary*. Nonmonetary criteria may be thought of as having nonmonetary *means* with monetary *ends*, in the sense that no dollar values are expressed immediately, although monetary consequences are expected. For example, better morale now may reduce costs later. Or, nonmonetary criteria may be thought of as being nonmonetary in both *means* and *ends*. That is, better morale is "good" of itself because people should be happy, regardless of costs. The latter type is based upon a value system which attaches importance to a multitude of intrinsic satisfactions not at all related to economic considerations. These infrequently perceived values of decision-makers may well lie at the root of some management decision rules and may explain the presumed irrationality of nonprofit maximizing behavior.

OPERATIONS RESEARCH

According to Churchman (5, p. 108), operations research activities do not necessarily attempt to maximize profit. An essential characteristic of the operations research approach is its pursuance of an optimum decision relative to a system or subsystem. This optimum decision may refer to a combination of objectives such as the following: to decrease production costs, to render better customer service, to increase the share of the market, to maintain stable employment, to retain product leadership, to preserve good relations with the community. Since these objectives are often in conflict with one another and since it is impossible to simultaneously maximize two or more conflicting criteria, a compromise is inevitable.

Hitch and McKean (12, p. 170) state that full optimization requires simultaneous consideration of all possible allocations of one's resources, consideration of the probable impacts of all exogenous events, and the maximization of *some* utility function subject to *certain* initial constraints. Particularly in dealing with problems involving conflicting interdepartmental objectives, it is necessary to consider more than just one broad objective. Churchman (5, p. 115) suggests a method for weighting each of the several objectives so that various courses of action can be evaluated quantitatively. He recommends that this weighting be done through a ranking procedure by averaging the importance placed on each of the objectives. Although the obtaining of optimum solutions in this manner is conceptually feasible, the usual procedure consists of attempting to suboptimize sequentially the many interdependent segments of the business system.

Suboptimizing refers to the quest for the best course of action in relation to a reasonably attainable goal by optimizing a subsystem (24), while optimization seeks the somewhat ideal solution of optimizing the whole system. Almost any system is a subsystem of a larger system—the department is a subsystem of the plant, the plant is a subsystem of the firm, etc. Hitch and McKean (12, pp. 179-183) consider the relationship between higher and lower levels of suboptimization. Some of their comments are summarized as follows:

1. The test for suboptimization criteria should be, if possible, that the lower level criteria are consistent with the criteria at the next higher level.
2. When criteria at two vertical levels are not in agreement, certain allowances must be made on the lower level decisions in order to compensate for this variation in the two criteria.
3. A common mistake in selecting suboptimizing criteria is to concentrate only on a single input; for example, maximum output per direct labor hour, which excludes the cost of material, capital equipment, and supervision (to mention only some of the excluded items). Where possible, interest should be centered upon an overall optimization function.

The realization of profit maximization is dependent, at least, upon adherence to these specifications.

There is no assurance that an actual situation is being optimized merely because results from the solution of the mathematical model are being followed. It is virtually impossible for mathematical models to represent conditions as complex as those existing in the real world.

The results of any mathematical analyses which are to be applied to an operational situation must be moderated subjectively by evaluating the effects that any of the variables which were omitted from the mathematical model may have upon the solution. Also certain assumptions usually are either postulated or statistically tested in order to facilitate the solution. The degree of possible deviation of any assumptions from actuality must be assessed. The results from the solution of mathematical models of operational situations will not in general produce a unique, absolute answer but rather one that must be subjectively modified. A question arises as to

how the subjective modification effects the presumed profit-maximizing function.

It is appropriate to distinguish between reliability and validity with reference to mathematical models that are simulating real world situations. Reliability refers to the consistency of a measure to produce under repeated tests similar results when conditions are similar; validity refers to the degree to which predicted results correspond to actual results. As a practical matter, only a subjective appraisal can be made regarding the validity of a specific technique for maximizing profits. This subjectiveness results because it cannot be ascertained when profits have reached a maximum value, under different conditions. Most of the mathematical techniques of operations research are reliable; it is their validity which may be doubtful; it is questionable validity which casts doubt upon their ability to maximize profits.

Various measures of effectiveness are used in mathematical programming. It should be noted that the criterion used is often not necessarily compatible with profit maximization. Presently, linear programming is a popular technique for assisting in arriving at operational decisions under certain specific conditions. Extreme care must be exercised in ascertaining the appropriateness of linear programming. The linearity assumption, if not appropriate, may lead to results which are neither optimum nor sufficiently accurate to warrant use of this powerful tool. Again, effects upon profit may not be insignificant.

Salveson (23) uses total idle time of the workers on the assembly line as a criterion for balancing the work loads at the different stations. As a result of Salveson's having formulated this assembly line problem into the simplex method of linear programming, idle time was reduced from a previous value of 15 percent to 5 percent after the results of the linear programming solution were applied. This criterion of minimizing idle time appears to be compatible with the criterion of the next higher level, that of reducing costs. However, Salveson concentrates on a single input, labor; it might have been more advantageous to concentrate on motion study, or to obtain a higher level of automation. Accepting the physical system as given may result in fallacious optimization of subsystems and whole systems.

Reinfeld and Vogel (20, pp. 161-164) present a case problem in which the objective is to do a given amount of work with a minimum of production time. It is reasonable that this objective could be proper for management under certain conditions although such an objective is not identical to maximizing profit. Reinfeld and Vogel (20, p. 107) also point out that goals within a department are not constant; they may vary from time to time. As an example, consider the case of a machine shop that has missed several promised delivery dates. The present goal of this machine shop is to maximize the number of prompt customer deliveries. After the backlog of orders diminishes, the shop may become more cost conscious and the chief goal might then switch to maximum profit or to some other goal.

QUALITY CONTROL

The use of cost minimization as the sole criterion for establishing a statistical quality control plan may lead to undesirable results because various important intangible factors are omitted from consideration. The following advantages of statistical quality control have been listed by Shewhart (25, p. 34):

1. Reduction in the cost of inspection.
2. Reduction in the cost of rejection.
3. Attainment of maximum benefits from quantity production.
4. Attainment of uniform quality even though the inspection test is destructive.
5. Reduction in tolerance limits where quality measurement is indirect.

The degree to which these advantages are achieved is dependent upon the level of quality desired, which is dependent upon the costs of achieving quality and the demand for relative quality. If management were interested in minimizing costs, the desired quality level would be such that the marginal value of quality added is equal to the marginal cost of increasing quality (22). Juran (14, p. 7) states that the optimum (quality level) is always short of perfection. It would appear that neither management nor quality control practitioners attempt to determine or achieve the optimum.

Management may desire product differentiation as a basic objective; it may wish to distinguish its products from those of competitors. One means of achieving this product differentiation is by producing products at a quality level higher than that justified by purely economic considerations.

The corporation may be in an oligopoly market situation in which price changes cannot be made by one corporation without fear of retaliatory actions by other firms in the oligopoly group. However, non-price competitive tactics, such as producing excellent quality products or services, are accepted as being proper competitive actions. A high level of quality may aid in attempting to attain the objective of maintaining or improving the company's market position.

Any statistical process control plan or statistical acceptance inspection plan can be uniquely defined by specifying two points on the operating characteristic curve (2). These two points correspond to the probability of accepting the process as being in a state of control about the desired mean value when it is in control and the probability of accepting the process as being in a state of control about the desired mean value when the process has shifted to a new mean value. These points usually are specified arbitrarily by management with little or no concern for the costs involved. A higher level of quality may be specified by the manufacturing department than

would be warranted by cost considerations alone so that the sales department will not be prone to complain about the "poor" quality produced by the manufacturing department.

INVENTORY CONTROL

Most of the considerations given inventory control procedures by economists and mathematicians have treated conditions in which the objective was to minimize the combined costs of setup, storage, and shortage. Such an objective may not be compatible with the goals of most business management.

Holt (13, pp. 14-22) has dealt with the case in which the cost of inventories is minimized subject to the constraint that the total investment in inventories is equal to a certain value. Such a model will not necessarliy maximize profits.

One of the costs in the commonly used cost minimizing function of inventory theory is the cost of a shortage. Determination of this cost is complicated by the various intangibles involved in "disappointing" the customer. Talbird (26) in his thesis proposed to allow the decision-maker to determine the cost of shortage indirectly by having him arbitrarily specify the probability of a shortage that will be tolerated. This procedure does not necessarily lead to cost minimization; indeed, cost minimization is quite unlikely.

Discrimination often is involved between the customer who is internal to the organization and the usual external customer. An example of the internal customer is the machinist who exercises a demand for sheet metal upon the stock room. For an internal customer like this, it may be possible to determine the actual costs of a shortage by compiling costs that would be incurred in obtaining the needed item through an expediting procedure. However, management's policy may be to establish arbitrarily an unreasonably low or unreasonably high probability of a shortage for items that are for internal use, i.e., unreasonable from an economic standpoint. To some extent, this may be true also of the external customer.

It is possible that management may consider an interruption in its industrial processes as a cause of more intangible harm than merely the tangible costs due to the lack of the part. Frustrations may be caused by shortages since the employees may feel that management does not have the proper foresight to anticipate such potential shortages. In addition, management may take pride in running a "smooth" organization. These reasons plus the awareness of management that the achievement of maximum profits is not actually its objective may explain the apparent reluctance of management to adopt profit-maximizing proposals as designed by many Industrial Engineers.

Where the customer is external to the organization, the concept of good will is involved in policies regarding the stocking of items. It would appear reasonable for management to have a high regard for good will because of its presumed long-term consequences. For security reasons, caused by the lack of knowledge as to the consequences of customer reactions to shortages, management may tend to favor an inventory policy which will result in extravagant stockage service to its customers. If management wants to improve or maintain its market position, anything less than excellent stockage service to customers will deteriorate market position, provided the competition can provide a similar product with better stockage service.

If the argument cited above concerning shortages is accepted, it will be unnecessary in many cases to cost a shortage; management will need only to specify the probability of shortage that it will accept, supposedly considering nonmonetary factors as well as monetary factors. When this probability of a shortage is specified, an imputed cost can be determined which quantifies both tangibles and intangibles in terms of dollars for the cost of a shortage. This cost may be used as an indicator of the dollar value actually placed on shortages. Both Churchman (5, p. 211) and Vazsonyi (27, pp. 307-309) have described practical procedures for evaluating the imputed costs of a shortage.

There are a number of reasons why the traditional economic lot size formula is not adequate for certain business conditions. It is not always the desire of management to minimize the total overall inventory costs. There may exist a more pressing corporate issue. For example, money may be needed for investment in other areas, producing more of a demand for money elsewhere than for maintaining "optimal"[6] inventory quantities. A new phase of the business cycle may be in sight, and prices of items may be expected to change. This change in the business cycle may require quantities different from that of the established optimum because of the speculative motive.

Several difficulties may arise in the physical procedure of ordering lots and doing setups. These difficulties may generate a desire to order lots of larger size than is optimal. Welch (29, p. 35) mentions the possibility that management might have goals other than minimum total cost. As alternatives, he mentions the goal (supposedly interim) of reducing inventory without increasing the number of orders and the goal of reducing the number of orders without an increase in the cost of inventory. Churchman (5, pp. 255-273) proposes a method of finding the best lot size when costs cannot be minimized because of the limited availability of a fixed asset, or production time, or a combination of both.

It would seem to follow that rational management is not necessarily interested in an absolute cost minimum;

[6] The word "optimal" is used here in conjunction with the quantities that would be used if stocking were strictly carried out via the economic lot size formula.

and, therefore, Industrial Engineers should not establish inventory control systems with the exclusive objective of minimizing total costs. Such systems easily could lead to results incompatible with the true goals of management.

CONCLUSIONS

It is clear that the principles and practices of Industrial Engineering are based upon the premise that the Industrial Engineer functions to facilitate the execution of policy as conceived, interpreted and executed by management.

The objectives of business management in the United States economy are not necessarily profit maximization nor cost minimization. The objectives of business management differ from firm to firm, from time to time, and may vary with changing conditions.

Some of the effects of management's nonprofit-maximizing behavior upon Industrial Engineering activities are as follows:

1. Intangible considerations may outweigh tangible considerations in the analysis of proposed methods improvements.
2. The optimum decision in using the operations research approach may consider, in a quantitative manner, items that are usually thought of as intangibles.
3. Because of pride or because of a desire for product differentiation, management may cause a level of quality that surpasses the level which would obtain if intangibles were not considered.
4. Higher inventory levels than those corresponding to cost minimization may be maintained so that plant operation will be smoother or so that customer good will will be maintained.

Since the role of the Industrial Engineer is to assist management in the execution of its objectives and since the objectives of management are not necessarily consistent with profit maximization and cost minimization, then the principles and practices of Industrial Engineering should not necessarily premise cost minimization nor profit maximization as primary management criteria.

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A Statistical Analysis of Whole-Dollar Accounting

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WHOLE-DOLLAR accounting is sometimes called penny-elimination accounting (1). These are the names of a development in accounting technique used by a number of businesses. Among the better known organizations using this system are Bethlehem Steel Corporation, Colgate-Palmolive Company, Pan American World Airways, Inc., Time, Inc., and Electric Boat Company.

The writer hastens to remark that whole-dollar accounting is different from whole-dollar reporting. Whole-dollar reporting is merely the elimination of the cents when publishing final accounting statements, e.g., profit and loss statements, manufacturing cost statements, and balance sheets. Whereas, whole-dollar accounting involves the elimination of carrying the pennies or the cents throughout the accounting procedure of posting entries in the firm's internal accounts. Of course, it is necessary to retain these cents in such ledgers as accounts payable, bank accounts, and petty cash since they are external accounts.

For example, assume that the firm purchases an item and the vendor submits a statement involving dollars and cents. The account payable for that vendor is posted in dollars and cents. However, when the item is debited to the stores-account, the amount is rounded to the nearest whole dollar. When the item is drawn from stores and charged to manufacturing and subsequent accounts, it is carried through the system in dollars only.

ADVANTAGES

There are a number of advantages in using the whole-dollar accounting method. One is that it results in fewer absurd changes and presents a more sensible face to the customers. For instance, in the case of manufacturers of heavy equipment, e.g., cranes, earth-moving equipment, trucks, aircraft, ships, submarines, it would seem ridiculous to charge a customer \$X,000,000.78 or even \$X,000,001.

A second advantage is that a great deal of savings in accounting expenses can be realized. Many items are posted from one account to another a number of times before the final posting. Whole-dollar accounting eliminates the necessity for carrying the pennies and the decimal place throughout the entire system. If the accounting is done with electronic business machines, three digit places are eliminated. This permits more flexibility in the system. The savings become significant when one considers that there are many thousands of entries handled through the internal accounts each business day.

Many firms indicate that the clerical savings amount to as much as 40 per cent (6). If entries average on the overall five digits and a decimal point, say \$344.56, then eliminating the decimal point and the pennies, i.e., rounding to \$345, reduces the number of keys punched from six to three. If the decimal is assumed, as is done in many cases, the number of digits is reduced from five to three.

A third major advantage is that the opportunity for errors is reduced somewhat, especially in that portion of the work in which human error is involved. There are two less columns to deal with. A reduction in the number of columns reduces the total number of errors. This assumption was confirmed in an experiment reported by Mr. Jagolinzer (5).

Also, errors that do exist are more easily recognized. One author reports a talk given by a controller to a group of finance officers (4, p. 58). He gave an example using the following addition:

\$605.91
3.99
20.26
\$629.16

The error in addition is not as readily detected as it would be if the values had been rounded to the nearest whole-dollar before adding:

\$606
4
20
\$629

In the latter case the error is more conspicuous. A great deal of time is spent in finding the source of errors; therefore, whole-dollar accounting has the advantage that errors are more likely to be caught before they are carried through the subsequent accounts to the trial balance.

It is recognized that many accounting systems permit the retention of a limited amount of error rather than incur the expense of pinpointing the source. Usually the tolerances are small; therefore, the probability that an investigation will be necessary is apt to be reduced by using the whole-dollar accounting method. Another reason for using whole-dollar accounting is that inflation has made the pennies less important than they formerly were.

In general, management has been reluctant to adopt whole-dollar accounting in spite of the advantages of the

system. The chief argument seems to be that elimination of the pennies will result in an intolerable degree of inaccuracy in the internal accounts. We should not be too quick to condemn this attitude. The literature on the subject has generally expounded the advantages but has consistently neglected to report any statistical analysis of the behavior of the method. Furthermore, the writer contacted several companies that use this system and they all indicated that they had not made a statistical analysis of the effects of rounding in any of their internal accounts.

Without being concerned with statistics at all, one can say that the maximum possible mistake in any single whole-dollar accounting entry is fifty cents. The worst situation would occur when a rounding of fifty cents was made on every transaction. This is obviously absurd, but it does represent an upper bound. Also, if the average amount for each transaction is $1.00, the mistake due to such rounding would be a relatively large proportion of the total amount of all the transactions. However, this proportion would seem trivial if the average amount for each entry was $10,000.

The proponents of whole-dollar accounting assume that rounding involves an "error" effect rather than a "mistake" effect, i.e., that one rounding is upward, the next is downward, etc. It is also commonly assumed that the average of the distribution of the penny values greater than fifty cents is seventy-five cents, and that the average of the distribution of the penny values less than fifty cents is twenty-five cents. If this is so, the estimate of the amount of error due to rounding for a number of transactions is:

$$(\tfrac{1}{2} \times 25¢) - (\tfrac{1}{2} \times 25¢) = 0$$

A STATISTICAL STUDY

The author made a statistical study of the accounts of one large company which is considering the adoption of this accounting technique. One phase was to study the empirical distribution of the cents ($X.00 to $X.99). Three accounts were investigated: accounts payable, direct labor, and stores. Pages of entries for each of these accounts were selected at random, in accordance with a random numbers table, from the records for an entire fiscal year.

The object was to check whether there was a bias in the division of accounts with regard to the frequency of values smaller than fifty cents compared with the frequency of values larger than fifty cents. Also, since amounts of precisely fifty cents are rounded to the nearest *even* dollar, the evaluation included the frequency of odd or even dollars associated with values exactly equal to fifty cents. The long run proportion of instances that rounding up occurs is expected to be ½, therefore, the proportion of instances that rounding downward is expected to take place is $1 - \tfrac{1}{2}$. Hence the binomial probability law is applicable.

A *chi square* test confirmed this assumption. The large number of entries examined, two thousand or more, from each of the accounts made it permissible to employ statistical tests founded on the normal curve. If the number in the sample is large and np' is greater than five, the chances of getting various relative frequencies in the sample will be given approximately by the normal distribution (2). In this case, if p_1 is the probability that an entry is rounded downward and p_2 is the probability that an entry is rounded upward, the null hypothesis may be stated as $p_1 = \tfrac{1}{2}$, or $p_2 = \tfrac{1}{2}$. The alternate hypotheses are, of course, $p_1 \neq \tfrac{1}{2}$ or $p_2 \neq \tfrac{1}{2}$. Since a two-tail test is indicated, the chance that the relative frequency will deviate from ½ by as much as $k\sigma_p$ is given approximately by the area under the normal curve above $z = k$ and below $z = -k$. The standard deviation (σ_p) is given by

$$\sigma_p = \sqrt{\frac{p(1-p)}{n}} \qquad \text{(3, p. 445)}$$

The tests did not reject the null hypothesis in any of the three accounts. The statistical evidence was very strong in the case of the accounts payable and the direct labor accounts.

However, the calculated test statistic for the stores account was quite close to the critical test statistic value. An investigation revealed the cause.

A shop order is issued for each authorized job. Parts and material used in fabrication are charged to the appropriate shop order number. In some cases a single fabrication job may require a number of identical units of a certain part or material. Evidently it had become the practice to write a number of requisitions, each for one unit, rather than to order all the units on one copy. For example, one full page of entries was for the same material code item, all charged to the same shop order on a series of requisitions bearing consecutive serial numbers. A calculation of the statistical test with n based on the number of shop orders (indepedent entries in the sample) rather than on the number of stores requisitions (total number of entries) gave support to the argument that the distribution of the roundings in a given direction for this account was not entirely random. It is conceivable that a large number of such entries, each for the same amount, could introduce a bias which might be serious in any penny-elimination accounting system. The extent of this practice was not realized prior to this study.

A COMPARISON OF METHODS

During the initial phases of the research, certain accounting records were kept using both systems. The object was to study the discrepancy between the two methods. A monthly trial balance was made for each of the accounting plans and the individual values were compared by testing the null hypothesis that $\sigma = 0$ for the paired observations. The alternate hypothesis is $\sigma \neq 0$. The appropriate test statistic is Student's t:

$$\text{calculated } t = \frac{\bar{d} - 0}{(\sigma_d)/\sqrt{n}} \qquad (7, \text{ p. } 103)$$

where $\bar{d}$ = mean difference between paired values and

$$\sigma_d = \sqrt{\frac{n\sum d^2 - (\sum d)^2}{n(n-1)}}.$$

At the 99 per cent confidence level the statistical analysis did not reject the null hypothesis, thereby confirming that the overall final results did not indicate significant difference between the trial balance figures taken from the two accounting methods.

Following formal installation of the plan, a so-called monthly rounding balance account is maintained to record the cumulative balance of the discrepancy between the internal (rounded) accounts and the external (non-rounded) accounts. At the time of this writing the balances for this account have all been well within what the accountants called permissible.

The statistical operations performed for this work resulted in the incidental finding that it is folly to post direct labor charges to the nearest penny in other than payroll accounts. In this company the policy is for the men to charge their time to a shop order number to the nearest quarter-hour. Assume a mean direct labor rate of $2.50 per hour. The records show that a worker is involved on an average of 2⅔ different job assignments (shop order numbers) per shift. Theoretically, fractions of ⅛ hour or less are dropped; and fractions greater than ⅛ hour are upgraded to the nearest quarter-hour. The long run mean error is equal to or less than ⅛ hour.

$$\frac{1}{8}\text{ hour error} \times \frac{\$2.50}{\text{hour}} \times \frac{8}{3}\,\frac{\text{job changes/man}}{\text{per shift}}$$

$$= \$0.83\,\frac{1}{3}\,\frac{\text{error/man}}{\text{per shift}}$$

Under this assumption a check was made to see whether the dollar-per-manpower unit error is significant compared to the rounding error incurred by whole-dollar accounting.

The statistical test rejected the hypothesis that the dollar-per-manpower unit was not significant. However, it is admitted that the contribution of the inaccuracy due to the treatment of rounding the time to ⅛ hour puts this source of error in an extremely unfavorable light when it is compared with the inaccuracy contribution due to penny elimination accounting. In other words, in this case, there is considerably more error in rounding to the nearest quarter manhour than in eliminating the pennies in the posting.

SUMMARY

The statistical tests employed support the several claims commonly made for whole-dollar accounting. The importance of using statistical analysis in a particular situation before the adoption of such an accounting system was illustrated when the test was applied to the stores account. In the case of this company the bias due to irregular practices in submitting stores requisitions might not have otherwise been detected.

The main argument against changing to whole-dollar accounting was answered by the results of this study. The statistical analyses showed that the degree of inaccuracy was not significantly affected when whole-dollar accounting was practiced and that the final trial balance figures compared favorably. If accuracy is the factor at issue, it frequently can be shown that certain policies and practices introduce greater inaccuracy than is experienced through rounding to the nearest whole dollar. The procedure of rounding time charges was an illustrative example.

According to these findings the whole-dollar accounting system has much to recommend it.

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Work Sampling in an Engineering Design Department*

by **M. WOLF**

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AS AN initial step in the development of improved planning, scheduling and control procedures for ship design workload in Naval Shipyards a work sampling study was conducted in a shipyard Design Division. The purpose of the study was to record the proportion of time spent in the various functions performed and to obtain an objective picture of the level of activity so that more realistic planning factors could be applied to the workload.

PREPARING FOR THE STUDY

Excluding staff and service groups which were not to be included in the study, the Design Division consisted of fifteen line sections having a total complement of 314 people. For reasons of economy the actual sampling was limited to seven of these sections having a complement of 142. It was considered that a thorough coverage of seven representative sections would yield results applicable to the line organization as a whole.

To assure a valid sampling it was decided to obtain at least 400 observations of each individual sampled. And, it was desired to complete the study in a two-week period. This meant that 40 observations per employee would have to be made daily.

TRAINING THE OBSERVERS

Seven observers were assigned to the director to form the study group. Of these, three were design people experienced in the work to be sampled, and three were experienced work sampling observers borrowed from another department. One day was spent instructing the observers. Those from Design Division helped the others to recognize those things that go on in a design organization while those experienced in work sampling pointed out the techniques of making observations. Also, the group was instructed in the work categories to the point that they would uniformly interpret each category. Each observer was permanently assigned to one of the sections to be covered and in this orientation period visited his section to familiarize himself with the people and the work. It would have increased the randomness of the study and reduced any influence that personal judgment exerts on the recordings if observers were rotated among the sections. However, since the recordings were to be made so as to distinguish the job classification of each employee observed, it was necessary for the observers to be able to recognize the employees and there was not sufficient time for each observer to become acquainted with each employee in all seven sections.

ORIENTING EMPLOYEES TO BE COVERED

Prior to commencing the study, the director held stand-up meetings in each of the selected sections, explaining the purpose and nature of the study. A clear explanation put the employees at ease and encouraged them to work normally during the study.

WORK CATEGORIES

The work of the organization to be studied was broken down into a total of 36 categories. These categories were developed with the assistance of the supervisors. They were tested during a preliminary two day trial run of work sampling and were finally firmed-up by the time of commencement of the study. These categories are listed in Table 1.

ADAPTATION TO ELECTRONIC DATA PROCESSING

Since the observations were to be processed on electronic data processing equipment it was necessary to codify the information to be recorded. Each observation was to be distinguished by:

1. Work Category
2. Job Classification
3. Section
4. Time (by quarter hour)
5. Date

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* *The authors and reviewer are to be particularly complimented for their willingness to simultaneously display the original study and the subsequent critique. This emphasizes one of the long range objectives of the Institute as discussed on page S7, Volume XII, Number 2a, of the JOURNAL.—Editor*

TABLE 1

Results of Study

Work Category	Percent Occurrence*		
	Non-Supervisors	Supervisors	Total
Productive—Direct			
11—Drawing Layouts and Sketches	6.9	3.1	6.1
12—Drawing Finished Drawings	18.1	1.3	14.5
13—Drawing Revisions	4.4	0.3	3.5
14—Design Memorandum	0.4	0.5	0.4
15—Calculation—Design	1.4	1.4	1.4
16—Bill of Material—Rough	1.0		0.8
17—Bill of Material—Final	0.7		0.6
18—Material Requisition	0.1	0.9	0.3
19—Reference for Drawing	5.5	1.0	4.5
20—Reference, Bill of Material	0.8	0.2	0.6
21—Reference, Other	4.5	3.2	4.2
22—Checking Plans	1.7	2.0	1.8
23—Hull Survey	0.1	0.6	0.2
24—Correspondence Preparation	0.7	2.6	1.1
25—Reading Correspondence	0.6	2.5	1.0
26—Writing Office Memos	0.1	0.7	0.3
27—Supervisory (Technical)		21.6	4.7
28—Supervisory (Administrative)		10.2	2.4
Total	47.0	52.1	48.4
Productive—Indirect			
30—Reading Technical Material	0.2	0.6	0.3
31—Consultation	14.6	14.9	14.7
32—Telephone	0.3	2.1	0.7
33 Beneficial Suggestions	0.1	0.1	0.1
34—Work Setup and Clean-up	4.5	1.2	3.8
35—Miscellaneous	2.0	1.4	1.6
Total	21.7	20.3	21.2
Personal			
38—Available	11.6	5.5	10.3
39—Not Available	2.9	2.1	2.8
Total	14.5	7.6	13.1
Away-on-Business			
40—Technical Library	0.2	0.2	0.2
41—Plan File	2.8	1.1	2.5
42—Visit Ship	2.0	3.4	2.4
43—Visit Shop	0.5	1.3	0.7
44—P&E	0.3	0.6	0.3
45—Mock-up	4.4	2.2	3.9
46—Other Design Code	4.3	5.4	4.5
47—Conference	0.9	4.2	1.6
48—Training Course	0.1	0.6	0.2
49—Miscellaneous	0.9	1.0	1.0
Total	16.4	20.0	17.3
Grand Total	99.6	100.0	100.0

* Based on a total of 59,017 observations, 12,720 of Supervisors and 46,297 of Non-Supervisors.

Work category codes are shown in Table 1. Job classification codes are as follows:

Job Title	*Job Code*
Supervisory Engineer	01
Supervisory Engineering Designer	02
Engineer	03
Engineering Designer	04
Draftsman	05

The seven sections were coded 01 through 07. Numbering systems were also devised for time and date. An IBM mark-sense card was devised for recording observations.

MAKING THE OBSERVATIONS

Each day a different table of random times was used listing the times for observers to commence their rounds of observations. For each observation the observer used a separate card, mark-sensing the employee's job code and applicable work category code. Employees leaving their desks during the day indicated where they were going on a chit and were recorded by the observer under the applicable "away" category. Employees on leave were not included in the study while in such status.

On completion of each round of observations the observer attached a header card to his mark-sensed cards. The header card was prepunched with the quarter hour of the day in which the round began. At the end of the day the cards were labeled as to section and date.

Approximately 60,000 observations were obtained, 12,700 of supervisors and 46,300 of non-supervisors.

Because the nature of the functions performed by supervisory personnel differs from that of non-supervisors separate tabulations of results were made for each of these two groups as well as for both combined. In thus segregating the data we obtained greater homogeneity and therefore greater reliability in our analyses and conclusions.

RESULTS OF THE STUDY

Table 1 shows the percent occurrence for each work category. In Figure 1 these values are grouped into the four major areas of work distribution as follows:

Productive (direct)	categories 11-28
Productive (indirect)	categories 30-35
Personal	categories 38-39
Away-on-Business	categories 40-49

With the observation data recorded by work category, job classification, section, time and date it was possible to make a number of different analyses.

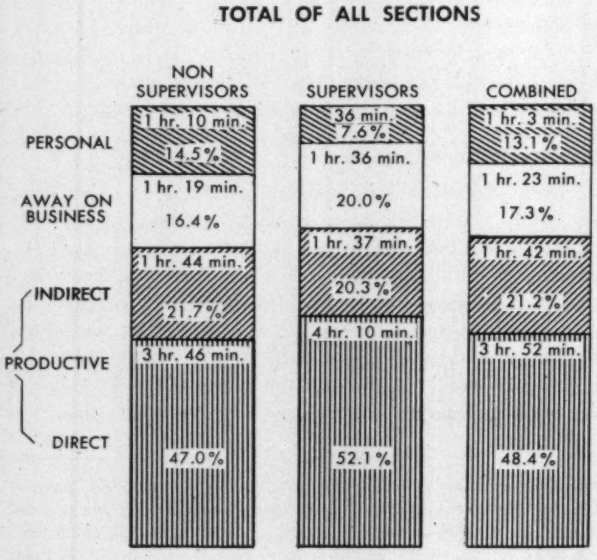

FIGURE 1

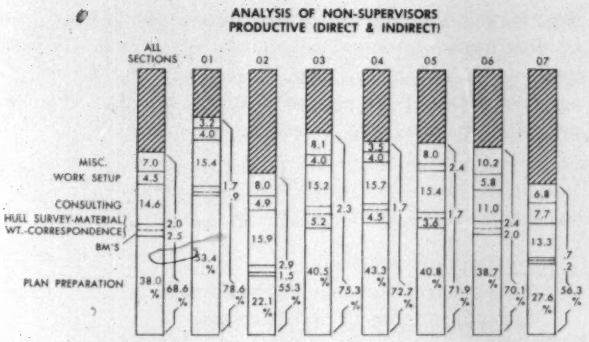

FIGURE 2

Figure 2 shows by section the productive time of non-supervisors with work categories grouped according to type of work. "Plan Preparation" consists of categories 11-13, 15, 19 and 22. "Bill of Material" (BM) consists of categories 16, 17 and 20. "Hull Survey, etc." consists of categories 14, 18 and 23-26. "Consulting" is category 31. "Work Setup" is category 34. "Miscellaneous" consists of categories 21, 30, 32 and 35. Analysis of the chart highlights areas for further study for improved performance. Relative uniformity among the sections in certain categories indicates standard proportion of time spent by the organization as a whole in these functions, and this is useful information in workload planning. A similar analysis was made of supervisors' productive time.

Away-on-Business was analyzed in order to identify the extent of time spent away from the section according to the places visited. Such information should be useful in planning for revisions in methods, procedures and space layout. Figure 3 gives the proportions of away time by place visited. The results show that most of the away time is spent in other design areas such as at "mock-up" and plan files.

A breakdown by job classification is given in Figure 4. Here, proportions are shown according to the four major areas of work distribution. Work category 31, Consultation, which is included in Productive (indirect) is also shown separately. By this chart, management is made aware of differences in employee utilization according to job classification. Significant variations can be further analyzed to determine areas where better employee utilization is warranted.

A further breakdown by job classification according to selected categories of productive work is shown in Figure 5. The pattern of work distribution was interpreted as indicative of good assignment of work.

Analyses were also made by time of day and day of week. In the analysis by time of day a definite negative correlation was found between "Personal" and "Away-on-Business"—when one was high the other was low in a like amount. It was concluded that this correlation was caused by utilization of a portion of "away" time to ac-

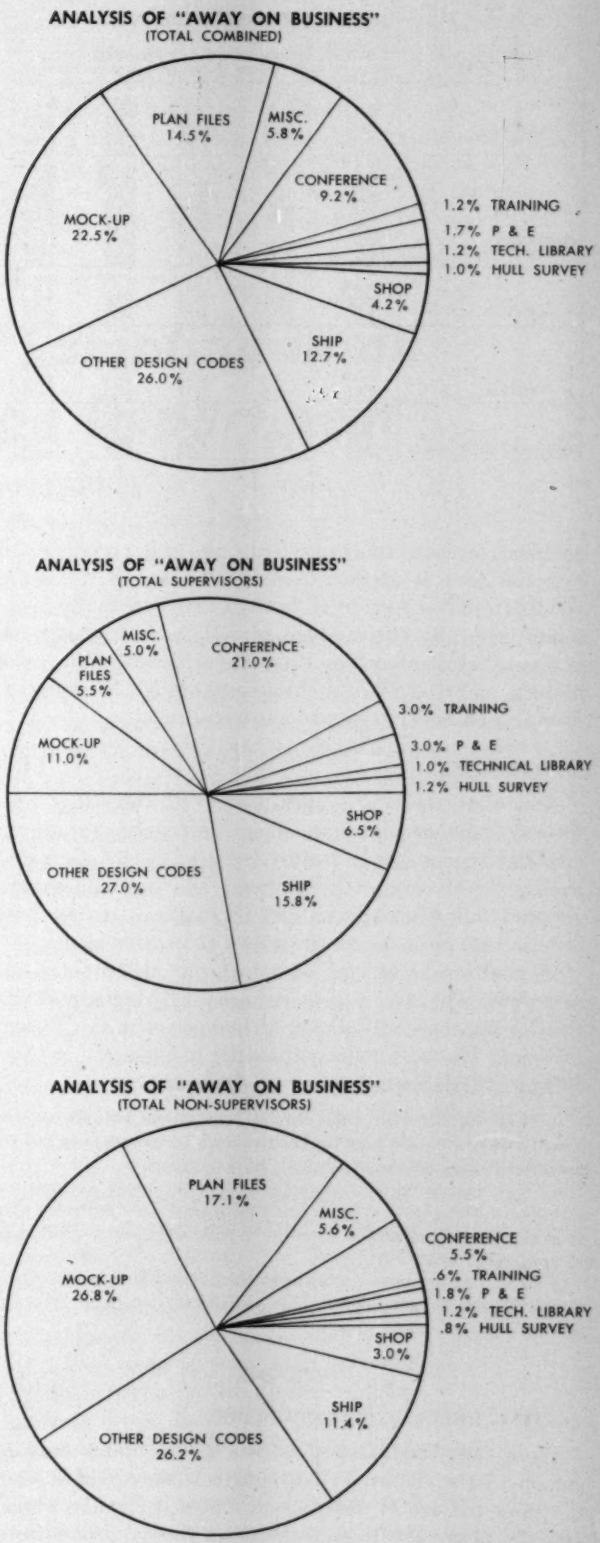

FIGURE 3

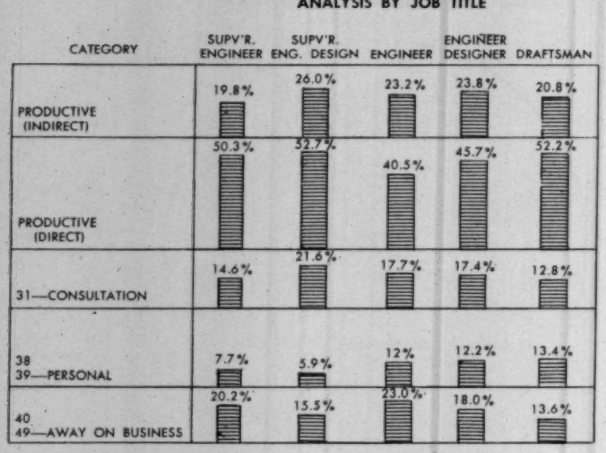

FIGURE 4

complish personal functions. Thus, the true proportion of personal time is greater than that shown in the study results in that a portion of "away" time is actually "personal" time. By the analysis of results by day of week it was demonstrated that Productive (direct) time has a pattern of being high on Monday through Wednesday, dropping off on Thursday to a low on Friday.

CONCLUSIONS

Now that there is a measure of the functions performed, management has objective criteria to use in establishing manpower requirements to meet anticipated workload. As improved methods and procedures are adopted follow-up studies can be made to revise these criteria and to measure the effect of improvements.

In addition to serving as a measure of the functions performed, the results point out areas offering opportunities for improved utilization of manpower in the Design Division. The best opportunities are in the areas of Consulting, Available and Away-on-Business.

a. High consultation time should be examined to determine cause. Possible causes may be unclear work assignments and work assignments beyond the capability of the assignee.

b. Work category 38, "Available," is about twice as high for the non-supervisors as it is for the supervisors. This indicates that it could be reduced and is therefore a potential source of increase in productive time.

c. Most of the away-on-business time was found to be spent within Design Division areas. This has already led to revisions in office layout and procedures.

APPENDIX

TESTING RESULTS FOR PRECISION

Work sampling is based on the theory that a random sample of the elements composing a whole tends to have the same pattern of distribution that exists in the whole, and the larger the sample the more closely this pattern of distribution is matched. The degree to which the sample matches the pattern of distribution of the whole can be determined by standard statistical methods. By such methods we obtain the level of accuracy of the percentage occurrence of the various elements sampled. The formula for obtaining a 68% confidence level is:

$$s = \sqrt{\frac{p(1-p)}{N}}$$

s = standard deviation
p = percent occurrence of the element
N = total number of observations

Applying this formula we obtain a confidence interval which is the "p" obtained by sampling, plus or minus the standard deviation. We can expect that the confidence interval will cover the true value of p approximately 68 times out of 100. To obtain a confidence level of approximately 95%, two standard deviations are obtained:

$$s = 2\sqrt{\frac{p(1-p)}{N}}$$

An application of this formula to the work sampling study is as follows:

Drawing (work categories 11, 12 and 13) by non-supervisors equals 29% of their time. A total of 46,300 observations were made. Therefore $p = 29\%$; $N = 46{,}300$

$$s = 2\sqrt{\frac{.29(1-.29)}{46{,}300}} = 2\sqrt{\frac{.2059}{46{,}300}} = 2\sqrt{.000004447}$$

$$= 2(.002109) = .00422 \quad \text{or} \quad .4\%$$

This means that we are 95% confident that the interval of $29\% \pm .4\%$ contains the true p value. Therefore, in 95 cases out of 100, the actual occurrence of the element will fall between 28.6% and 29.4%.

Applying the formula to category 38, "available,"

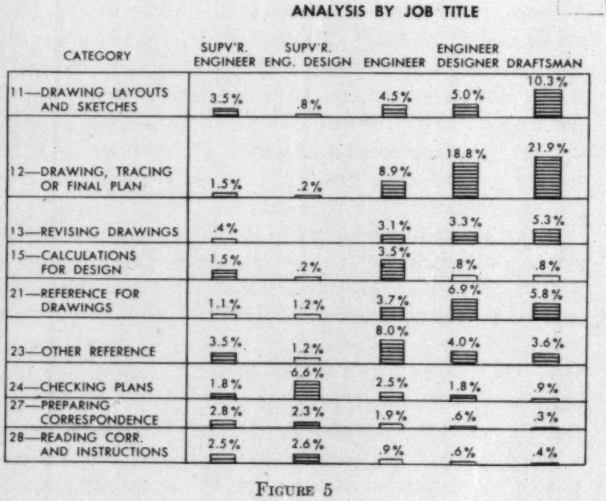

FIGURE 5

which is 11.6% of non-supervisors' total time the confidence interval is 11.6% ± .3%. This means that we are 95% confident that non-supervisors are in category 38 between 11.3% and 11.9% of the time.

For non-supervisors it was considered that a high degree of statistical precision had been obtained even for functions constituting low percentages of total time. Such high precision was not obtained for supervisors since the aggregate number of observations was much smaller. However, when work categories are grouped according to broad functions a high precision is obtained. For instance, supervisory categories 27 and 28 combined have a value of 31.8%. With the total number of observations being 12,700, this gives a confidence interval of 31.8% ± .8%. Thus the range for 95% confidence for the combined categories is between 31% and 32.6%.

Comments on "Work Sampling in an Engineering Design Department"

by **JOHN M. ALLDERIGE**

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THE PRESENTATION reflects a reasonably typical study currently done by Industrial Engineers. The area of application is certainly of interest and the mark-sensing and punched-card procedures associated with work sampling are in need of re-exposure from time to time. However, this article also portrays a traditional "number-getting" analysis that Industrial Engineers, quite frankly, can move away from, to their enormous benefit. These notes are a critical comment from one in the profession concerned with engineered or designed measurement based on the decision-making needs of the problem—as opposed to what might harshly be called "measurement-for-measurement's-sake" attitude suggested throughout the presentation.

MEASUREMENT DESIGN COMMENTS

The purpose of the study is well stated at the outset. The authors envisioned their study "as an initial step in the development of improved planning, etc. . . ." and stated its purpose ". . . to record the proportion of time spent in the various functions performed and to obtain an objective picture of the level of activity so that more realistic planning factors could be applied to the workload." Given this perfectly reasonable purpose and given the restrictions set forth in the following paragraph of only covering half of the total sections (more will be said on this later), there are rational, specific procedures that *are* available for the designing of the measurement. These apparently were not used in this study and produced a study involving more observations than would appear to be necessary on statistical grounds. The basis of a designed study is in noting what tolerance is permitted in the percentage of each category and then calculating the sample size using the formula or its nomographic equivalent such as that found in Barnes' *Work Sampling.*

This matter was not discussed at the outset of the article, rather was it reserved until the very end, implying that the same thinking prevailed in the study. All sample size decisions were apparently made rather casually such as the decision to obtain at least 400 observations on each person sampled. This was ostensibly "To assure a valid sampling. . . ," but there is a real question as to the relationship between "validity" and the 400 observations per person proposed. Part of the question lies with the individual worker—the avowed purpose of the study was to "record the portion of times spent in the various functions performed," hence it would seem that the concentration should have been on the functions for purpose of designing the study. Having decided on the appropriate sample size for a function, then allocation to the individuals in that function could have been made. Presumably, it was desirable to study different individuals since it was felt that there were major differences in the performance of the functions from individual to individual. This, in itself, is a statistical process and there could be an argument about randomly distributing the readings both in time and across people but the heart of the disagreement is more with the arbitrary assignment of 400 to an individual sample.

The functions of interest are presumably reflected in the selection of categories. The work "presumably" is used since there is some hedging at the end of the study in the aggregation of different categories into broader areas of work distribution and into less broad but still larger-than-category work type groups. In the subsequent discussion of various analyses there is some vagueness as to just how the data are to be used or can be used and here is the key to the matter. This kind of discussion, it is suggested, might always come first. If there

be thorough discussion at the beginning on just how the data might be used, such discussion would lead to some idea of just how right one needed to be on a particular category and, from that, a rational and reasonable study could be designed.

For instance, as noted in the Appendix, the "Drawing" work-type with non-supervisors amounted to 29% with a ±.4% confidence interval. Would the proposed action have been any different had that confidence interval been, say, ±1.2%? It doesn't seem likely—this reviewer's knowledge of such situations would suggest to him that ±3-5% would have been all right considering the kinds of decisions that can be made. But even with 1.2% the sample size of 46,300 would have been cut to 1/9 that size or about 5,000 or so—a substantial reduction in engineering time which amounted to close to 500 hours over the two-week period studied. The authors are correct to use absolute intervals in their construction—this is the only way in which the matter can be examined, particularly with the very small percents—.3%, .9%, etc. Talking relative precision, for this kind of study, makes no sense whatsoever. The whole criterion of "good precision" depends on the use of the data—on the kind of action that can be taken which dictates "how right" (precise) one has to be in absolute terms.

One more example to emphasize the point—consider category 38 as discussed under "Conclusions" and in the next to last paragraph in the article. This is noted as being "about twice as high" for non-supervisors—it is listed as 11.6% with a confidence interval of ±.3%. This is really much too precise to detect the kind of difference that was, in actuality, needed to be detected and that would have required only 5,400 observations in total, 1/8 of the study volume. Probably ±2% would have been all right requiring only 2,000 to 2,500 observations in total. Thus, examination of the decision-making needs can bring vast economies into the study itself.

The above may seem to be more of a hindsight analysis rather than beforehand analysis necessary for design. This brings out the vital importance of a preliminary study which the authors did, and the interrogation of such a study just as has been done with the final study. Such questioning can bring out just what is needed in the way of precision in each of the categories and a designed study can be the result giving evidence of economy by Industrial Engineers which should go a long way toward the acceptance of our advocacy of it by others.

DESIGNING THE PLANNING

All of the previous comments have been based on the acceptance of the categories as listed. As the authors note, this study with its recording of the time proportions is considered "As an initial step in the development of improved planning, scheduling and control procedures. . . ." Just as one can ask questions regarding the precision requirements of a listed category, so can one ask questions as to whether or not the category is really necessary. We in Industrial Engineering have long had the questioning attitude regarding operations—not the least important question is, "Can this operation be eliminated?" The same thinking can be applied to our own analyses. The authors generally set forth the idea in their study that rather complete categorization was necessary—it is suggested here that if the scheduling problems were looked at in light of current knowledge of statistical and mathematical techniques that such detailed breakdowns might not be necessary. In other words, a large part of the measurement dollars could have been saved with a small part traded for study design dollars.

The general problem of scheduling and planning in an engineering organization has only been treated primitively to date. Interestingly enough, one of the major works has been done in the Navy—project PERT, recently reported in the *Journal of Industrial Engineering*. Without oversimplifying the results of that and other studies, it nevertheless is an impression that the planning and scheduling decisions that apparently can be made are rather gross and are not in need of detailed measurements—either great precision in categories of work or great detail of categories. It is harder to criticize the effort of these authors on this count considering the newness of the work in the engineering department field. Nevertheless, some awareness of other work done and the recognition that the measurement problem could not be tackled without more specific reference to the resulting planning system seems to merit comment.

Industrial Engineering is going through a very critical period. We cannot afford to let problems slip out from under us because of incomplete knowledge of what other disciplines are doing in our field. It would have been unthinkable, for instance, for a reasonably average operations research analyst to miss the overall implications of the planning and scheduling problem and at least a passing shot at trying to resolve that problem. Measurement might not have been undertaken on such a general basis although, quite frankly, the "overall implications" may have frozen the work at the "thought" level permanently. PERT demonstrates the point although it can be helped considerably by having more intelligent measurement than it does have. We have a long tradition and practice of work measurement—it had its genesis in an age when measure was separated from a schedule and a plan only by simple multiplication. As we move into more complex systems, however, this simple relationship no longer is the case; yet we must maintain that relationship in order to effect the labor control we presumably are aiming for. Labor control is only obtained at the plant threshold—through scheduling and planning, hiring and attrition. We can no longer measure just for the sake of measurement and this is desperately true in such an area as engineering. This reviewer is almost willing to say that the more time we spend in studying the

essential nature of the real problem and the less we spend in massive measurement, the better off we'll be.

CONCLUSION

All of this may seem to be a lot of noise about very little; this reviewer doesn't think so. The direct engineering time spent in this study was around 500 hours, probably twice that was spent altogether. It seems not unlikely that an ideal of 200 hours would have been possible had some of the design thinking suggested in this critique been employed. This might appear to be a harsh indictment of the work done. It is not so intended—it is rather intended to point up that additional analytical techniques can be put to work and can produce considerable benefit. Certainly one of the very real counter arguments that comes up is the need for "selling" the vast number of workers and managers who are totally unfamiliar with this kind of measurement possibility. One selling device is certainly the display of a massive collection of numbers that "prove" beyond doubt that certain things are indeed so. There is no quarrel with this need, but there might be a real question that Industrial Engineers need to ask themselves when faced with this problem, "Exactly how much more information is needed to make the sale?" Let's set forth the statistical requirements first and then see whether or not it takes 1.5 times, 2 times or 3 times that number to effect the sale. For every hour spent collecting numbers could be spent in convincing people and this critic suggests that the time might be more fruitfully spent, at least to some extent, in talking to people rather than collecting numbers. At least the statistical considerations and the design considerations will permit calling a spade a spade—will permit saying that this engineering time is to get the answer, and this engineering time is to convince people that the answer exists.

The study reported is not untypical of work that is being done in many other activities both in government and in industry. Again, this is not intended to be a derogatory comment on the people that are doing these studies. No one is more aware than this critic of the extremely difficult job it is to get started and to carry a massive job of this nature to completion. It is certainly true, moreover, that most analysts (such as in operations research) having more mathematical sophistication would be literally immobilized by the enormity of the task with its profound mathematical, technical and behavioral implications and not accomplish one iota as much as the "naive" Industrial Engineer who sees a job to be done and then proceeds to do it. The study as reported is not basically bad in any sense of the word; it is a considerable improvement over, say what was done five years ago and what is being done in many places today. But in what it lacks it is woefully short of what *can* be done. This postmortem is offered in that spirit and in the hope that it will lead other Industrial Engineers to build soundly on the good base that such studies as these represent.

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An Experimental Evaluation of the Validity of Predetermined Elemental Time Systems[1]

by **HEINZ SCHMIDTKE** *and* **FRITZ STIER**

Max-Planck-Institute for Work Physiology, Dortmund, Germany[2]

IN THE course of the last two decades a number of various predetermined elemental time systems have been developed, especially in the United States. These systems are designed to take the place of the traditional time study method in industry.

THE PROBLEM

This development sprang from the desire on the one hand to determine the time factors of a process more thoroughly and comprehensively than is possible with the very time-consuming stop watch and the chronograph methods, and on the other to eliminate the phychological difficulties which often result from direct time measurements at the work place. Starting from the principles of motion study, as put forth in many publications by Gilbreth, the authors of the various elemental time systems attempted, by way of the statistical analysis of motion study films, to isolate the basic motion elements and to determine their time values as dependent on distance moved, precision requirements, dead weight, etc. The authors of the elemental time systems all start with the assumption that the elemental time values thus determined may be added or subtracted like mathematical quantities. After the determination of the time values for all types of basic motion elements and work elements, it is possible to subdivide any operation into its elements, to read the time values of these elements from the standard data sheet, and to determine the necessary total time for the operation by adding up the elemental time values. One generation after Gilbreth the method toward which he worked but which he never developed seemed to be obtained, a method which would determine, once for all, valid time values for motion elements, by means of which it would be possible without any observation at the work place to calculate the necessary operation time by the mere knowledge of the sequence of elements within the operation.

Even when one looks superficially at the methodical basis of predetermined elemental time systems, it becomes obvious that the concept underlying these systems is almost identical with that of elemental physiology and elemental psychology. However, physiology and psychology have long ago advanced beyond the era of elemental thinking. Various findings of muscular physiology, neurophysiology and especially of Gestalt psychology have proved the mechanistic-static concept of life advocated since the time of Descartes to be untenable. This concept has been gradually replaced by a dynamic and functional concept of living organisms. The elementally mechanistic approach of the predetermined elemental time systems has thus to be considered a relapse into discredited beliefs of experimental physiology and psychology.

The development of elemental time systems, however, is interesting from other points of view. Since these systems may be used for the development of standard times

[1] This report is based upon a publication by Drs. Schmidtke and Stier, *Der Aufbau komplexer Bewegungsabläufe aus Elementarbewegungen*, Westdeutscher Verlag, Köln und Opladen, 1960.

[2] The Max-Planck-Institut fur Arbeitsphysiologie, founded in Berlin in 1912 and established at Dortmund since 1929, has the general task of studying the physiological and psychological fundamentals of human achievement under various working conditions. Upon Dr. Ralph M. Barnes' suggestion some of the results of the work at this institution have been summarized in this presentation.

for incentive work, basic mistakes in method must necessarily lead to false standard times. Apart from the consequences for wage negotiations, false standard times may result in excessive or too low demands on the worker, depending on the kind of error. While too low a demand is primarily of economic importance, an excessive demand over a long period of time may be injurious to health. These possible injurious effects on health are the reason that work physiology and work psychology set themselves the task of dealing critically with the principles and details of predetermined elemental time systems.

GENERAL METHODOLOGY

All predetermined elemental time systems are based on the concept that the majority of human activities may be broken down into basic elements of constant duration, and thus may be measured and tabulated once for all. It is the task of the work study man to determine the elements required to perform any present or proposed operation and to read their time values from the tables. In accordance with the rules of procedure of elemental time systems, the total time for this operation is obtained by adding up these elemental time values. Such a detailed examination of the process should enable the work study man to discover inadequate or superfluous elements and thus to improve the work method. This improvement must necessarily lead to a critical examination of production devices, tools, machinery, jigs and fixtures and of the product. The necessary coordination of establishing work time and carrying through methods engineering as well as their reciprocal effect is considered to be one of the most important advantages of these systems.

Although the basic principle previously explained is the same in all systems, the systems vary considerably as to the selection of elemental motions and the definition of them. The limits of this discussion do not permit giving examples; however, these may easily be found in technical literature dealing with the subject.

GENERAL CRITICISM ON THE BASIS OF PHYSIOLOGICAL AND PSYCHOLOGICAL FINDINGS

All predetermined elemental time systems are based on the assumption that the sum of the individual time values for motion elements is equal to the total time of a complex motion pattern. This assumption is a typical example of the mechanistic way of thinking prevalent in the biological sciences a hundred years ago. Thus, in the early stages of sensationalism and associationism, the whole of a perception was explained as consisting of a sum of elemental perceptions linked through association, which in turn were considered to be the components of complex impressions from the outside. These psychic processes and the outwardly demonstrated actions were thought to be built up from individual elements which together formed the whole of a perception or action. In an analogous way it was customary in psychology to explain complex reactions as consisting of a combination of reflexes linked in a chain-like manner. However, just as increasingly complex ways of thinking had to be developed in associationism, in order to integrate new kinds of observation into the system, it was difficult for physiologists concentrating on reflexes to explain the different effects caused by the various positions of the body. In the theory of reflexes, too, there had to be created further auxiliary concepts such as the concept of "switching," in order to be able to maintain the elementally-mechanistic approach which was customary since the times of Descartes.

The most striking suggestions that led to the overwhelming of the mechanistic viewpoint within the biological sciences came from the founders of Gestalt psychology. In his work on perceptual psychology Von Ehrenfels (5) pointed out, even before Wertheimer, Koffka and Köhler, that perceptible wholes are characterized by a certain "form quality" (Gestaltqualität). According to him, Gestalt is not only more than the sum of its parts, but also something different (3). Thus, an isolated study of components and their synthesis will never cover the Gestalt-structure of an entity, as was convincingly proved by the research of Wertheimer, Koffka and Köhler on optical perception. Not only in the field of perception, but also in the field of motion has the Gestalt-psychological approach led to a substantiation of Ehrenfels's explanation of the relationship between the sum of parts and the whole. The research carried through by Klemm (10) and his staff (11) (15) (20) (21) (24) on the motion pattern during physical training showed that a systematically arranged motion pattern is more than a single action, because the whole pattern comes off more exactly, more smoothly, and more quickly than its components. More recently, V. Weizsäcker (27) and his staff have notably dealt with the problem of human motions. They have criticized the dynamic character (Prozesscharakter) within Gestalt theory and have contrasted it with a functional way of approach. However, Weizsäcker also decisively opposes the physical way of thinking in biology.

The tendency within physiology for the theory of reflexes to explain the whole activity of the nervous system by reflexes has gradually faded away with the development of experimental neurophysiology, since it was realized that the theory of reflexes may at best give an explanation of certain functions of the spinal cord. This theory failed to deal with the spontaneousness of the central nervous system. Moreover, it was not possible to explain by a system of reflex chains the reciprocal effect of organism and environment, which V. Uexküll tried to demonstrate by means of the functional cycle (Funktionskreis), whereas V. Weizsäcker used the Gestalt cycle (Gestaltkreis) for the same purpose. With his investiga-

tions W. R. Hess made special contributions toward developing systems of coordinative processes of the central nervous system that, within his notion of the central nervous patterns, allow an understanding of the concerted action of sensory stimulus and motor response within an ordered action. The cybernetic approach, developed more recently, and the principle of reafference (Reafferenzprinzip), set up by V. Holst, have also contributed toward overcoming the theory of reflexes and making clear the predominantly functional character of the human machine.

When looking at the development of procedure and the theoretical concept of predetermined elemental time systems which are to determine the time required to perform certain movements, it becomes clear that in view of the further development of psychology and physiology (which we have described only in rough outline), the concept of a synthesis of the individual parts to a whole is based on the findings of a scientific era long gone by. Besides many deficiencies in method, this concept does not take into account the fact pointed out by Weizsäcker and later on especially by Klemm that the sum of the motion elements differs from the whole of the motion pattern. On the basis of his investigations of movements Derwort (4) was able to demonstrate very impressively that it is not necessarily the components that determine the effect within the individual section of movement but that, in anticipation, the actual happening is determined by the effect. Buytendijk (3) stresses the fact that there is a functional relationship between the duration and the form of a motion in such a way that the form is changed with different speeds and vice versa. This means that a certain form of movement cannot be explained from successive phases or elements of movement and their causality; but even if we suppose a causality, we have to recognize the fact that the simple addition or subtraction of motion elements does not lead to the intended aim of describing whole complexes of motions. This applies in the same degree to the form as well as to the duration of the motion.

Starting from this general criticism of predetermined elemental time systems, a number of experiments will be described in the next section. The results of the experiments will result in a special criticism of these systems that will be offered while answering individual, selected questions.

EXPERIMENTAL

In order that our sequence of investigations would not be split up into more or less isolated experiments, we tried to investigate the individual components of a motion, namely the direction of motion, the distance moved, and the precision requirements as a function of time, by starting from a study of the physiologically optimum motion time. Only after having carried through these experiments did we proceed to more complex motion patterns. Thus, we were able to find data that on the one hand allow a critical attitude toward the individual elements of elemental time systems and on the other hand enable us to make a fundamental contribution toward the criticism of this method.

THE PHYSIOLOGICALLY OPTIMUM MOTION TIME

The following investigations are aimed at developing motion times not by estimates or statistical methods but by measurements. These motion times may be called physiologically optimum and under certain conditions even "normal". At the same time, the effect of various factors upon the motion time were investigated, thus giving hints as to the necessary differentiation of standard data sheets as well as at the useful layout of the work place. The results described in this first section are cited from another publication of one of the staff members of the Max-Planck-Institute (22), since they are of fundamental importance to the present question.

METHOD OF INVESTIGATION

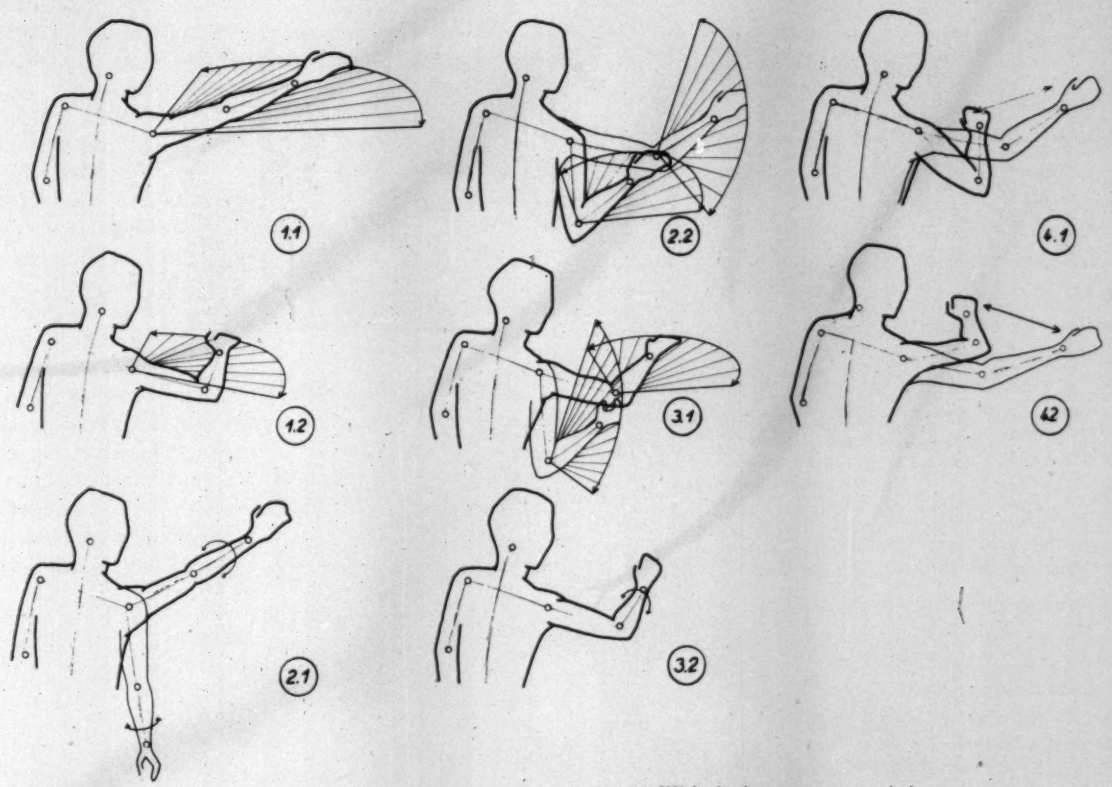
This investigation was limited to arm motions, which were subdivided as shown in Figure 1. As to weights, our investigations were limited to inertia.

A survey of the factors affecting the speed of arm motions shows that there are three essential groups of such factors:

The first group covers the predominantly mechanic variables:
Distance moved.
Moment of inertia of the arm.
Path of movement in relation to the body.
Motion time.
Gravity.
The second group covers psycho-physic variables such as:
The reciprocal effect of successive motion elements.
Conscious steering of the motion (for example a target motion which requires a high degree of precision).
The rhythm.
The last group finally covers a purely technical variable of work study:
The work effect.

The present investigation dealt with the mechanic variables which necessarily become effective with any kind of movement, although other variables may be superimposed on those in certain cases.

As to the method of investigation, the following assumptions are made: If there is a certain velocity of movement that, compared with other velocities, requires less energy per unit of motion, it is assumed that this physiologically optimum speed is used unconsciously under certain conditions; that means it may be called "normal". There are parallels between this and other kinds of motions, for example the pendulum-like movements of arms and legs when walking, which are normally performed at the most economical frequency, i.e. the natural frequency (14). This assumption holds true under the condition that the motion is well-practiced



1. Movements of the upper arm with the swivel point at the shoulder.
2. Rotations of the upper arm about its axis.
3. Movements of the lower arm.
4. Composite movements.

1.1 With the lower arm extended.
1.2 With the lower arm at an angle of 90°.
2.1 With the lower arm.
2.2 With the lower arm at an angle of 90°.
3.1 Around the elbow.
3.2 Around its axis.
4.1 Heterotropal movement.
4.2 Homotropal movement.

FIGURE 1. Kinds of Arm Movements.

and more or less performed without conscious control, i.e. without being directed by higher centers of consciousness or without being affected in any way by the variables mentioned above in the second or third group. Again, the performance of the motions may not be influenced by wage incentives, etc. Thus, it is presumed that under the conditions mentioned the "normal velocity of movement" is equal to the physiologically optimum velocity and may be determined by measuring the energy expenditure. This does not give any information on the "normal effectiveness of work," i.e. on the second component of the concept of normal performance, as defined by REFA (German Work-Study Association).

The experiment was carried out as follows (Figure 2): The persons experimented upon were sitting at a table, on top of which the paths of motion of the various kinds of movements were plotted and the distances were marked. This subject was asked to move his hands to and from between fixed points to the rhythm of a metronome. During this experiment his arms were held by two loops, in order to avoid the static muscular work of holding up the arms for 15 minutes. In the course of the experiment the expired air was measured by a respiration gas meter and analyzed for its content of O_2 and CO_2. From the result of the analysis the energy expenditure may be calculated. The experiment was carried through with three persons of different stature, as well as with arms of different lengths and weights, in order to find out the effect of the moment of inertia. The moment of inertia was further changed by weights held in the hands of the subjects.

RESULTS

Figure 3 shows part of the results of the experiments carried out on one of the three persons. The upper part of the figure shows the energy expenditure per minute plotted against the frequency of motions, i.e. against the rhythm of the metronome. The figures at the various

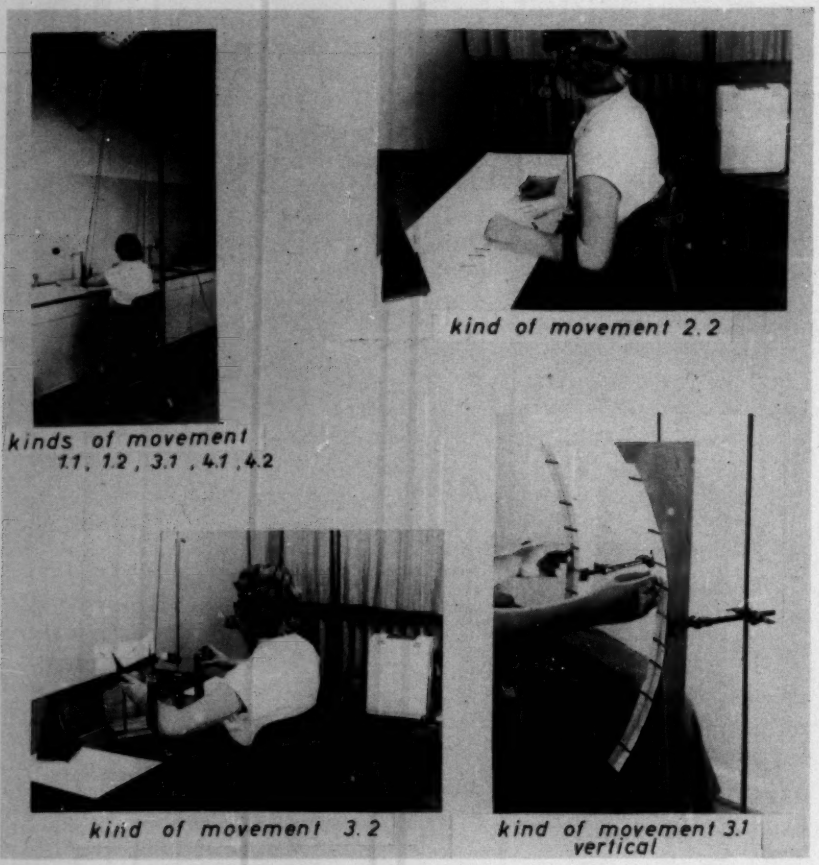


FIGURE 2. Experimental Arrangement for Measuring of Energy Expenditure during Arm Motions.

curves show the length of the distance moved, or, in the case of a constant length of 50 cm, the size of the weight carried by the hands. In this case, energy expenditure means that of kinetic energy only, since the basal metabolic rate had been deducted already. The lower part of Figure 3 shows the energy expenditure per motion. Here it may be seen that each curve passes a more or less marked minimum. These minima represent the points of optimum velocity which we were trying to fix. The accuracy of the curves is within 8-10% of the energy expenditure related to this work.

The maximum torques at the stopping points of movements performed at an optimum velocity were calculated and entered in a graph (Figure 4). The study of this graph leads to the assumption that there is a certain optimum torque for every group of muscles, so that the optimum velocity is determined by the maintenance of this torque. Moreover, when taking into account the cross section of the muscles involved, one comes to the conclusion that the maximum tensions of muscles at the beginning and end of the movement performed at optimum velocity are scattered over a relatively narrow field of 0.5 to 1.0 kg/cm^2 and that the tension of muscles may thus possibly represent the normal size of a feedback circuit (Regelkreis) of muscular action (2) (7).

On the assumption that there is a constant, optimum torque and a sine-shaped curve of the velocity of motion, the effect of the *length* of the distance moved and the *moment of inertia* on motion time may be expressed by the following formula:

$$t = C\sqrt{s \cdot \theta}$$

where C = (dimensional) constant, s = length of the distance moved, and θ = moment of inertia of the member moved.

Also, the time required to perform a motion is greatly influenced by the *path of motion* in relation to the body. When considering that the hand moves successively on different diameters of the circle shown in Figure 5, it becomes clear that the upper and lower arm are involved in these motions to quite a different extent. Measurements of the energy expenditure showed that the greater the optimum motion time, the more the upper arm is

involved in the motion. Starting from motions involving predominantly the forearm to predominantly upper arm motions, the counterclockwise movements become slower and slower. Here, the motion time increases by a maximum of about 30%. Depending on where the center of the hand motion lies on the work place, the directions mentioned are changed. Tangents to the unbroken lines of Figure 6 represent the directions of predominantly forearm motions. The circle with the differently tinted sectors is movable and has to be arranged at the place of the respective center of the motion so that the black sector runs parallel with the next unbroken line. Then, the increasing lightness of the sectors will show the direction of movements requiring increasing motion times.

The *duration* of motion was found by comparing swinging motions with those interrupted at both ends by breaks. Measurements of the acceleration proved that the isolated movement shows an increase in the maximum acceleration or deceleration by 10 to 15% as against the swinging motion, which means that the maximum torques are increased by this amount as well. With a constant optimum torque, this means that a person will unconsciously perform an isolated motion about 10 to 15% more slowly than a continuously swinging motion. Measurements of the energy expenditure showed that the energetic optimum of the isolated motion actually lies at a lower velocity.

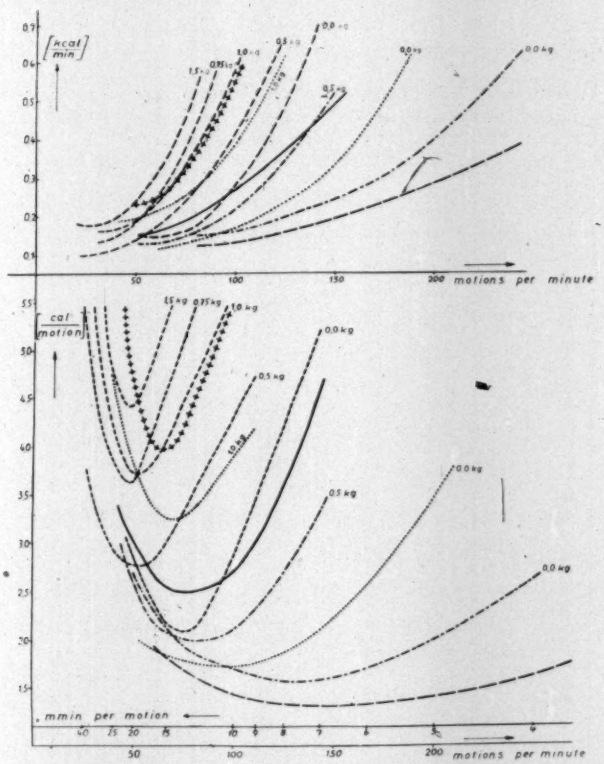

[kcal/min]
motions per minute
[cal/motion]
mmin per motion
Kind of movement 1.1
distance moved 10 cm
distance moved 18 cm
distance moved 30 cm
distance moved 50 cm
distance moved 50 cm with interruption at the stopping points of the movement
Kind of movement 1.2 distance moved 36 cm

FIGURE 3. Energy Expenditure during the Horizontal Movement of the Extended Arm (Subject *St*).

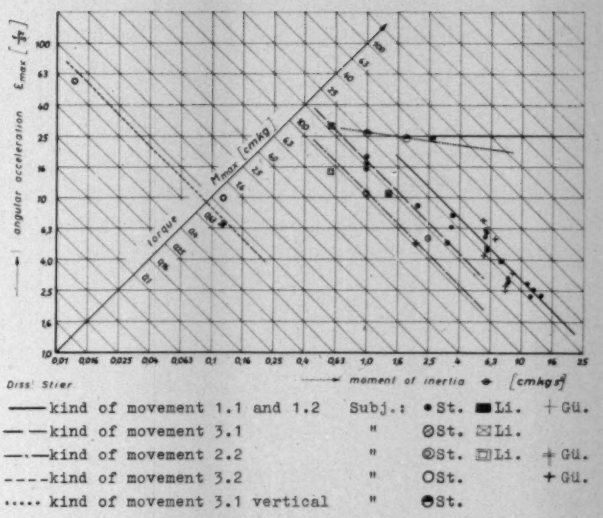


FIGURE 4. Optimum Torque of the Arm as Dependent on the Moment of Inertia and the Angular Acceleration.

Forearm motions were studied as to the effect of *gravity* on motion time. As was expected, the measurements of the energy expenditure showed that vertical movements cause a higher energy expenditure than horizontal ones. Surprisingly, however, the optimum motion time is shorter, i.e. vertical motions are normally performed more quickly than horizontal motions. Again, this motion time does not depend on the movement of inertia of the body-member moved, as was shown by experiments with various weights. Thus, vertical motions seem to be based on fundamentally different laws of nature, so that there is a certain constant relationship between the optimum motion time and the time for the free fall of the gravity center of the arm. This gives an explanation of the independence of the optimum time of the mass moved, since the time for the free fall does not depend on the mass of the falling body.

Figure 7 shows a summary of the results obtained. It shows the optimum time values as dependent on the length of the distance moved, on the kind of movement (see Figure 1) and on the weight transported. The time values are valid for the body measures given and for continuously swinging motions.

MOTION TIME AS DEPENDENT ON THE DIRECTION OF MOTIONS AT AN ARBITRARY VELOCITY OF MOVEMENT

The following experiments aim at examining the results found by means of physiological measurements at

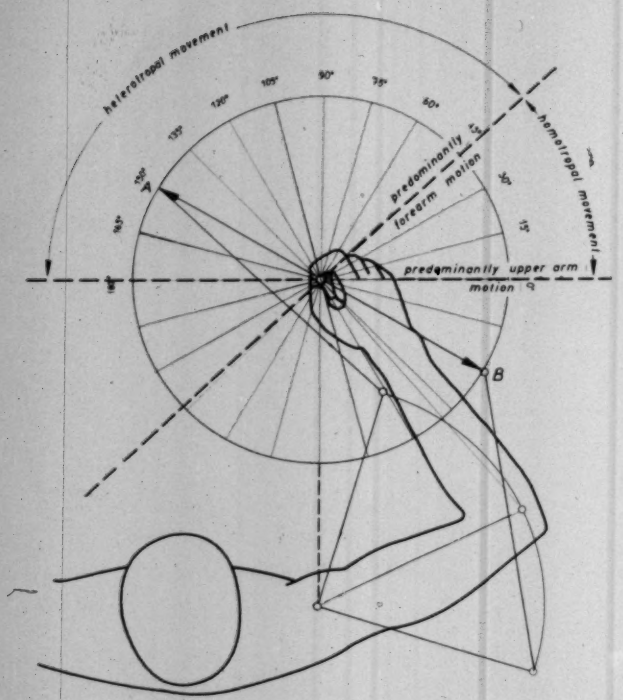


FIGURE 5. Angular Turning of the Upper and Lower Arm when Being Moved in Different Directions.

an arbitrary velocity of movement. This is to be done by studying the effect of the direction of movement in the horizontal and vertical planes.

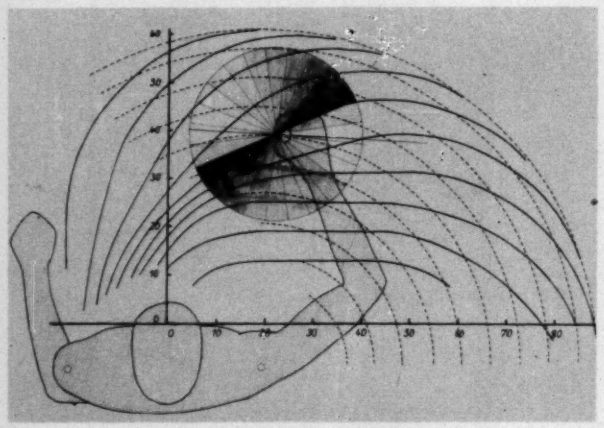
The experimental arrangement shown in Figure 8 was used for horizontal motions. The subject sat in front of a horizontal board with eight round contact surfaces of a diameter of 25 mm each, arranged in a circle of 40 cm in diameter. Any two faces lying opposite to each other in the circle represent a certain direction of movement. The board was arranged in a way that the directions of movement are at an angle of 0°, 45°, 90°, and 135° to the front plane of the subject. The subject was asked to move forward and backward in any direction, always touching the contact surfaces with the same finger. After any such motion backward and forward, it is repeated in the next direction following clockwise at a signal given at irregular intervals. Such a sign was given, because it developed that otherwise a certain rhythm of movement, bringing with it a synchronization of all motions, appeared. Every time the finger touched a contact surface, a circuit was closed, so that an electric registration became possible. The velocity of movement was left to the subjects.

These experiments were carried through with seven females of 18 to 22 years. The result of the experiments is shown in figure 9. Any point of a curve represents the mean value of about 200 measurements. With three subjects the standard deviation is shown by hatching. With all subjects the same mathematical interrelationship is to be noticed. Starting from 0° the motion time decreases to a minimum near about 45°, and from there it goes up to a maximum near about 135°. It may be assumed that the directions of movements arbitrarily fixed by the experimental arrangement do not coincide exactly with the directions of the maximum or minimum motion time. The trend of the results suggests that the shortest motion times are obtained at about 55° and the greatest ones at about 145°. In the lower part of Figure 9 these directions are to be seen. The mean values of all subjects are connected by a line. A comparison of this graph with Figure 6 will show very similar directions of the quickest motions, since at a point of the working area whose position corresponds to the center of the directional board (Figure 9), the direction of predominantly forearm motions is at an angle of about 52° to the front plane. As to the maximum motion time, it is improbable, as was assumed, that it is at the point where the ratio of upper arm swivel for forearm swivel reaches a maximum (white sector in Figure 6), but at the point where the upper arm swivel itself reaches a maximum. That means that the direction of the quickest motion is about perpendicular to the direction of the slowest motion.

PHYSIOLOGICALLY OPTIMUM MOTION TIMES AS COMPARED WITH THE TIME VALUES OF VARIOUS PREDETERMINED ELEMENTAL TIME SYSTEMS

It is now of interest to compare the physiologically optimum motion times which under the above conditions are assumed to be normal, with a great number of statistical data available in the tables of the various elemental time systems.

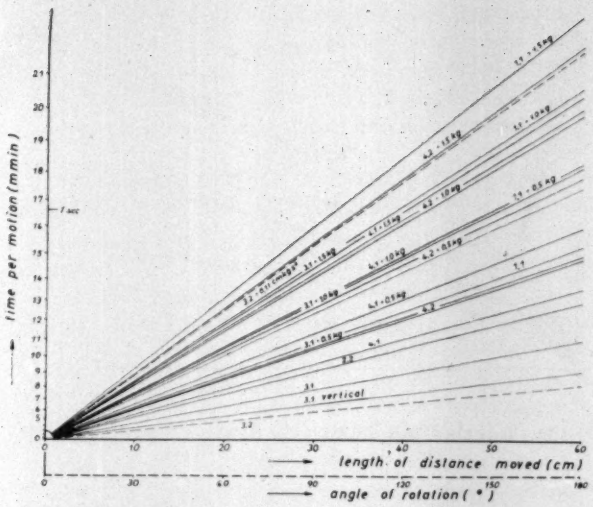
In order to carry through the comparison, we referred to the following systems:



——— predominantly forearm motions, favorable (example ◀)

– – – predominantly upper arm motions, unfavorable (example ◁)

FIGURE 6. Directions of Arm Motions at any Point of the Working Area.



Valid for persons of:
height: 174 cm weight: 70 kg
arm extended: Θ= 6.0 cmkgs^2; length = 70 cm
forearm: Θ= 1.0 cmkgs^2; length = 40 cm

for lighter arms the values are by 10.... 20 % lower

FIGURE 7. Motion Times as Dependent on the Moment of Inertia, on the Length of the Distance Moved, and on the Kind of Movement.

MTM—Methods Time Measurement (using the modified metrical tables of Haller-Wedel) (8).

WF—Work Factor.

BMT—Basic Motion Timestudy.

These systems were compared with our own experiments of moving the arm backward and forward between two fixed points and of rotating the forearm about its axis within a certain sector of the dial. For these motions a certain degree of eye control is necessary. The hand motions were allowed to deviate from the target by ± 3 cm, whereas a deviation of $\pm 10°$ was admitted for the swiveling motion.

Motions comparable to these movements were taken from the tables of systems cited. However, it became clear that it was not possible to make an exact comparison, since the motions of the individual systems are defined and classified very differently and above all are not differentiated to the same extent as the experimental motions described. No difference is made, for example, between a motion involving predominantly the forearm and a motion of the whole arm. Our experiments, on the other hand, proved that there is a difference whose extent cannot be properly neglected.

For reasons of comparison the following motions were selected:

MTM—reach, case *Bn*; move, case *An*; turn.

WF—arm movement (*A*), Work Factor *D*, additional Work Factor for weight, if any.

BMT—arm movement, reach or move, case *BV* turn, case *BV*.

In the Figures 10 to 13 comparable time values of American systems are plotted against the optimum time values obtained in these experiments. Our own values are shown as hatched fields, in order to take into account the different anatomical builds of the arms. When assuming that the "arm motions" of the American elemental time systems predominantly consist of those of the most frequent categories 2.2 and 4.1 (Figure 1), it becomes clear that the time values of MTM and WF for motions involving no weight are about 25 to 30% lower than the optimum values found during our experiments. This difference may possibly be explained by the fact that the two systems mentioned first are not based on our concept of physiologically defined normal performance, but on the average performance of incentive workers, which lies between 15 to 25% above normal performance. If it holds true that the reference magnitudes are different, it may be said that after having applied certain conversion factors, the time values of MTM and WF are almost equivalent to the optimum times. The relationship between the performance level of these systems and normal performance on the one hand and the relationship between the time values of the American systems and the optimum times on the other hand, is an indirect confirmation of the fact that under certain conditions the physiologically optimum time corresponds to the "normal time". In that case, an allowance of 20 to 30% has to be added when developing normal time by means of these tables. In fact, experience in some European industries showed that such an allowance is necessary. This allowance, however, is not sufficient, since the synthesis of a process from its elements leads to a so-called "chemically pure" time, whereas the actual time of REFA already includes small and minute breaks and allowances which, however, do not strike the eye as such. Thus, a further allowance whose amount depends on the working conditions is necessary.

When looking critically at this problem, the question could be raised whether there is any point in using pre-

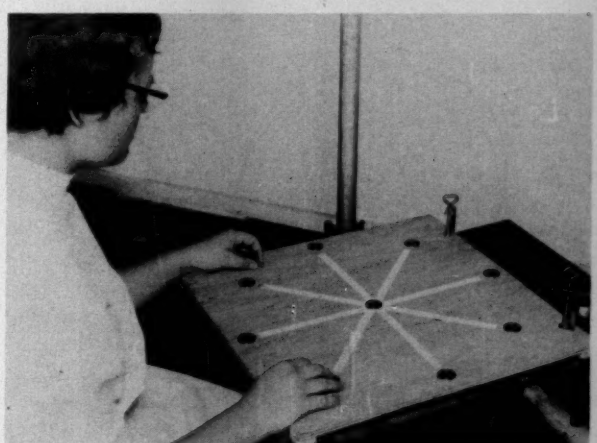


FIGURE 8. Experimental Arrangement for Measuring Motion Times at an Arbitrary Velocity of Movement.

determined elemental times for the development of performance standards and whether it can be justified under these conditions. If, to ascertain normal performance as defined in Germany, it is necessary to multiply a—let us suppose—correct sum of elemental times by a factor of 1.2 or 1.3 (a factor nowhere defined clearly) and possibly to add to the result a methods allowance (which again is not defined clearly), then, no doubt, more unstable factors whose magnitude is unknown are included in the final results than may be obtained with the traditional time study methods. Under this aspect, the use of predetermined elemental times must lead to a pseudo-exactness which is rather dangerous.

The corresponding time values of the BMT system are almost equal to the physiologically optimum time values. The fact that time values for grasping and releasing are included in the elemental time for arm motions may be the reason that the time values of the BMT system are almost equal to our own.

Moreover, the Figures 10 to 13 show time values for the transport of weights. The time values of the Work Factor system e.g., for transporting weights of 0.9 to 3.2 kg (or 0.45 to 1.6 kg for female workers) are shown by the

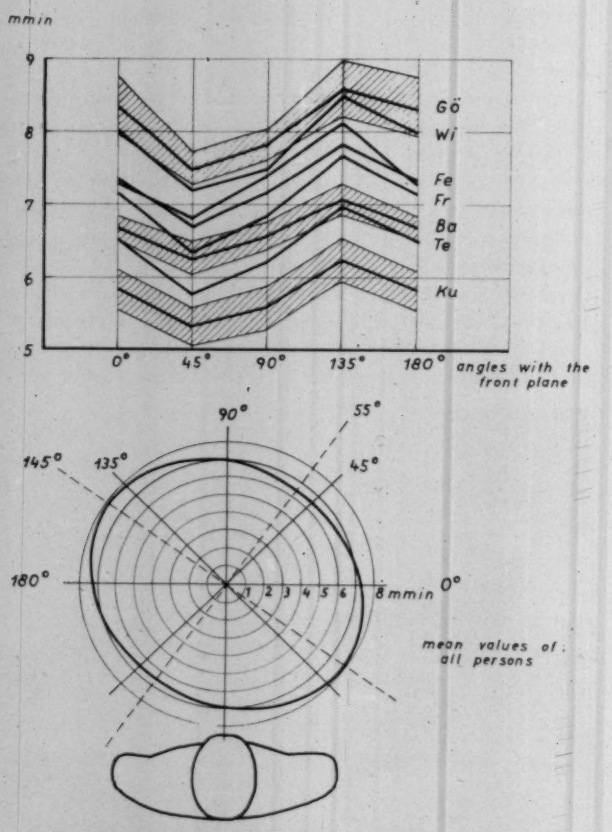


FIGURE 9. Effect of the Direction of Movement on Motion Time in the Horizontal Plane. (Distance Moved in All Directions = 40 cm.)

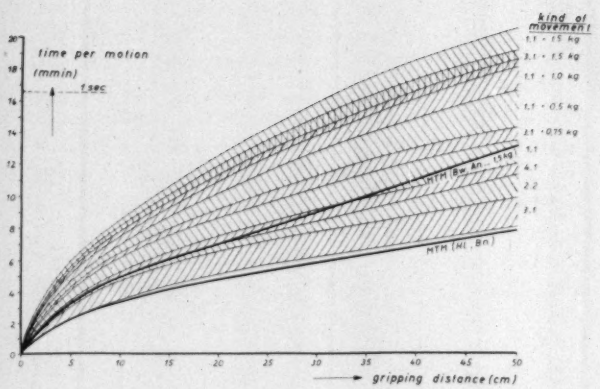


FIGURE 10. Comparison between the Times Values of MTM and Physiologically Optimum Times.

curve *ADW*. As an example of the MTM system, time values are entered that are valid from 0 to 1.5 kg. First, the great difference between the evaluation of weight within the two systems will be noticed. For an increase in weight from 0 to 1.5 kg the optimum values obtained showed an increase in transport time from 60 to 100%, depending on whether the predominant movement is of the forearm or the whole arm. As may be seen from Figure 7, the lower arm (type of movement 3.1), for example, is affected to a greater extent by an increase in weight than the whole arm (1.1). Thus, the allowances of MTM, WF, and BMT for weight seem much too low. (In this context weight means force due to gravity only, such as may be found when transporting weights by hand. As to the overcoming of frictional and spring forces, we made no experiments.) It must seem incredible that no increase in time will be noticed when carrying weights of 0 to 1.5 or 0.9 kg respectively. It is the very margin from 0 to 1.5 kg which is of extreme importance to industrial work, and thus it ought to be subdivided accordingly. A further increase in weight, moreover, causes a complete change of the motion pattern. Horizontal motions are more and more replaced by pendulum motions whose optimum speed is determined to a high degree by the natural frequency of the swinging pendulum. Thus, schematic allowances for all load grades are certainly incorrect.

Thus, this investigation shows that the motion elements may not be defined too cursorily, if exact time values are to be obtained. It becomes very clear that time values for the various kinds of movements (3.1, 2.2, 4.1, 1.1) are very different from each other. The results of our investigations show that an "arm motion" which, according to the WF system, requires 6.5 mmin (1 Work Factor) may deviate from those time values by 60%, depending on the path of the motion relative to the body. In their present form the American tables assume an exactness that does not exist. A high degree of exactness, however, is necessary to build up

a work pattern from its elements, since one mistake is multiplied by summing up. Besides, these very differences in time values which, for example, result from the different directions of movement are of high interest to methods engineering and ought to be used accordingly.

WAY-TIME RELATION OF TARGET MOTIONS AS DEPENDENT ON THE SIZE OF THE TARGET

One of the basic motion elements of all predetermined elemental time systems is the target motion of the arms not directed by a handle or a lever. All systems take into account that the time for the distance moved depends on the length of the distance, although the time values for the distance moved are not equal in the tables of the various systems. In the course of this investigation we shall frequently refer to this divergence between the time elements of the individual systems. As to the size of the targets, the fundamental agreement existing with reference to the way-time relation cannot be noticed. In this context the size of the target means the size of the object to be touched or grasped at a certain distance as well as the tolerance between plug and target during assembly work. The distance being equal, the precision of the motion will, no doubt, increase, as the size of this target and the tolerance decrease. These precise motions require additional time, since we know by experience that precise motions to a target require a greater motion time. The same applies to those cases in which a work piece has to be inserted into an open target for another one. The smaller the difference between the diameter of the plug and the target, the greater becomes the difficulty of the motion and the more time is required for its performance.

When examining the precision factors of the individual systems, the following becomes clear:

MTM System

MTM provides two categories of time values for such a target motion, depending on whether an object or only

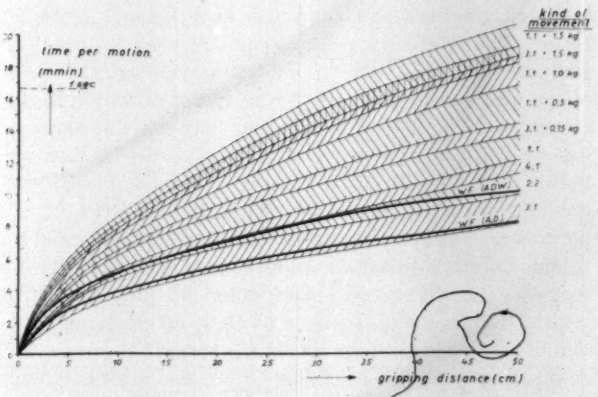


FIGURE 11. Comparison between the Times Values of WF and Physiologically Optimum Times.

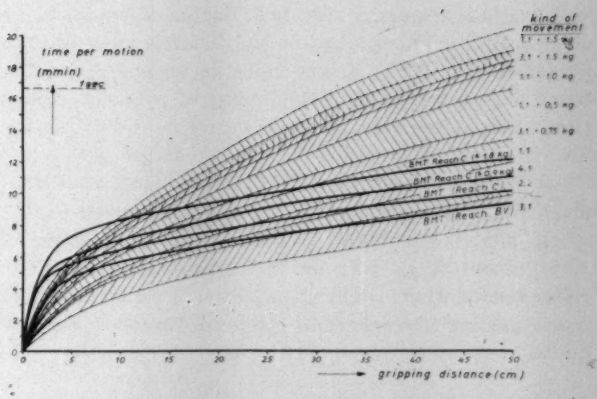


FIGURE 12. Comparison between the Time Values of BMT and Physiologically Optimum Times.

the arm and the hand have to be moved to a target. In case an object has to be moved to a target, the category of "move" has to be referred to; in the other case the category of "reach" has to be applied. Within the category of "move", there are three different classes of precision, whereas there are four within the category of "reach" (in this context a fifth class may remain unconsidered). These classes of precision differ only by their definition, i.e. no figures are given. For target motions a time value for precision (which is independent on the distance moved) has to be added to the times of the respective classes of precision. There are two classes of precision: tolerances of about 0.8 mm to 12.5 mm and tolerances below 0.8 mm.

Work Factor System

Work Factor provides a basic motion time (time for a free motion) that is dependent on the distance moved. In accordance with the precision required, one or two "Work Factors," which again are dependent on the distance moved, may be added to the basic motion time. With even higher precision requirements, additional time values (alignments) which are independent on the distance moved have to be added, as is done in the MTM system.

BMT System

Within the BMT system there are three different classes of precision for the motions of the arms and the hands. Moreover there are two subclasses for those motions which require visual direction. These five classes are dependent on the distance moved. Further five classes, which again are dependent on the distance moved, are provided for precision motions.

When summarizing the factors for the precision of motions within these three most popular systems of predetermined elemental times, it may be noticed that all of them provide different basic times, dependent on the distance moved, for different precision requirements. In

case motions require a very high degree of precision, an elemental time independent on the distance moved has to be added with MTM, a time value dependent on the distance moved within the lower range of precision, and a time value independent on the distance moved within the higher range of precision has to be added within the Work Factor system, while BMT provides an additional elemental time dependent on the distance moved for the whole range of precision. We shall have to examine to what extent these different methodical approaches are right and to what extent the additional elemental times corresponding to the various classes of precision are adequate.

METHOD OF INVESTIGATION

The way-time relation of target motions relative to the size of the target or the tolerance was determined with 11 subjects of between 17 and 34 years. The equipment used for the experiment consists of two contact disks of different diameters each in a cradle of insulating material. The cradle next to the body was fixed, whereas the second one could be adjusted on a strip of wood at every fifth cm along a distance of 5 to 60 cm. The time from touching the first to touching the second contact disk (Figure 14) was recorded. An electronic microchronometer was used as the recording mechanism.

The experimental subjects had to go through a training period of some time until no further improvement of their skill could be realized. Both as to the distances moved and the contact disks used, the main experiments were changed at random. Contact disks of 10, 5 and 2 mm in diameter were used. On the whole four main series of experiments were performed. During the experiments of the first series, contact disks of 10 mm in diameter had to be touched with the forefinger. With this experiment precision requirements were lowest. During the experiments of the second, third and fourth series a contact pin with a diameter of 0.2 mm at the point had to be used

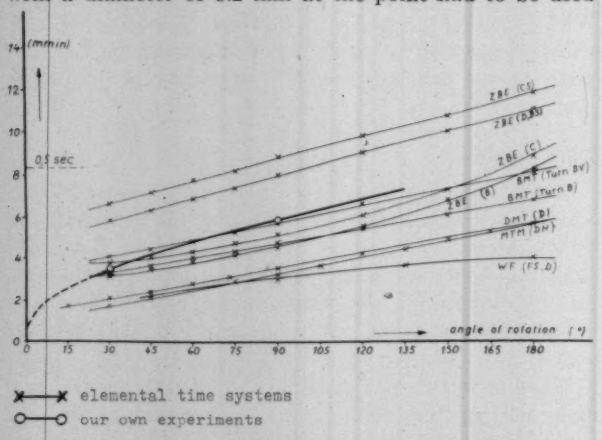


FIGURE 13. Comparison of Various Elemental Time Systems with the Energetically Optimum Values Motion Element "Turn" (Wrist).

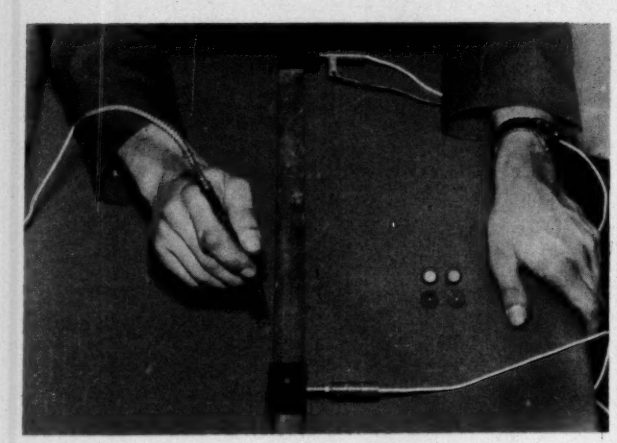


FIGURE 14. Experimental Arrangement for the Investigation of the Way-Time Relation with Free Motions to a Target. (The Contact Disks with a Diameter of 5 mm Are Inserted in the Cradle; the Disks of 10 and 2 mm in Diameter Are Lying to the Right.)

for contact making instead of the forefinger. It was pointed out in the experimental instructions that the speed of the motion had to be selected so that the target disk was touched in each case. During the individual series of experiments 20 travels to every grade of distance were registered for any subject. The individual travel consisted of 25 motions to a target. Thus, every measuring point is based on 5,500 individual measurements.

RESULTS

Figure 15 shows the way-time relations discovered during the four main series of experiments. The thick lines show the mean way-time curves of all persons, while the thin lines indicate the mean distribution. The curves showing the mean values as well as the boundary curves of the zone of dispersion follow the measuring points in an ideal manner so that a high reliability of the course of the curves may be inferred.

All of the four curves show the same steep slope at the beginning, with a clear break at a distance of about 10 cm. The relatively great amount of time required for short motions goes back to physical-physiological factors of the mechanism of motions pointed out at length in the literature (25) (26). The relation between the distance moved and the time required for the grades of distance between 10 and 60 cm is especially remarkable. In our opinion, the most important result of this series of experiments, however, seems to be the fact that, relative to the different precision requirements (in terms of the diameter of the target) the factor of proportionality within the grades of distance of 10 to 60 cm is not constant, but depends on the size of the target.

When plotting the curves of mean values found in the course of the four main series of experiments into a system of coordinates, as was done in Figure 16, it may

be seen from the set of curves that there exists a distinct relationship between way, time and the size of the target. The size of the target has a double effect. On the one hand the motion time required with a small diameter of the target is greater at any individual grade of distance than with bigger diameters, and on the other hand, the slope of the curves between 10 and 60 cm is the steeper with increasing distance, the smaller the diameter of the target.

Since the curves between 10 and 60 cm may be considered as straight lines, we calculated the equations for these lines as follows:

a. Diameter of the target 10 mm
$y = 0.0044\,x + 0.436$ (without contact pin).
b. Diameter of the target 10 mm
$y = 0.0074\,x + 0.466$ (with contact pin).
c. Diameter of the target 5 mm
$y = 0.0086\,x + 0.514$ (with contact pin).
d. Diameter of the target 2 mm
$y = 0.0104\,x + 0.696$ (with contact pin).

When looking at the relations quoted under b, c, and d, which resemble each other, since the target had to be touched in these three series by means of a contact pin, a general functional equation, i.e.

$$x(z, x) = a(z) \cdot x + b(z)$$

may be set up from these three equations for the field of definition of

$$2 \leqq z \leqq 10$$

$$10 \leqq x \leqq 60$$

The values for

$a(10) = 0.0074$ $\quad$ $b(10) = 0.466$

$a(\ 5) = 0.0086$ $\quad$ $b(\ 5) = 0.514$

$a(\ 2) = 0.0104$ $\quad$ $b(\ 2) = 0.696$

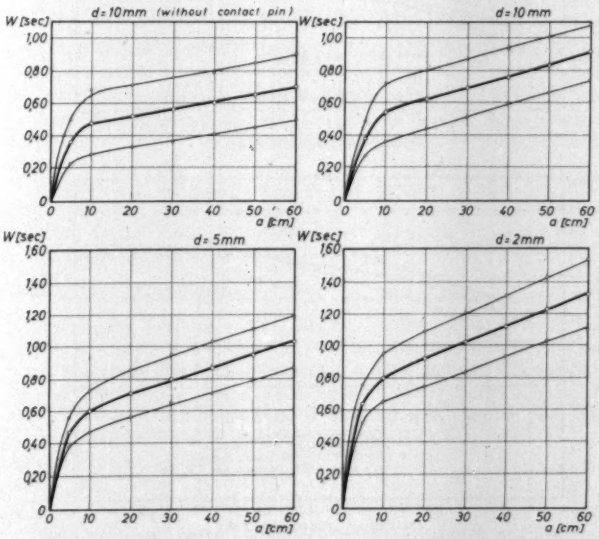


FIGURE 15. Way-Time Relation for Free Motions to a Target as Related to the Size of the Target.

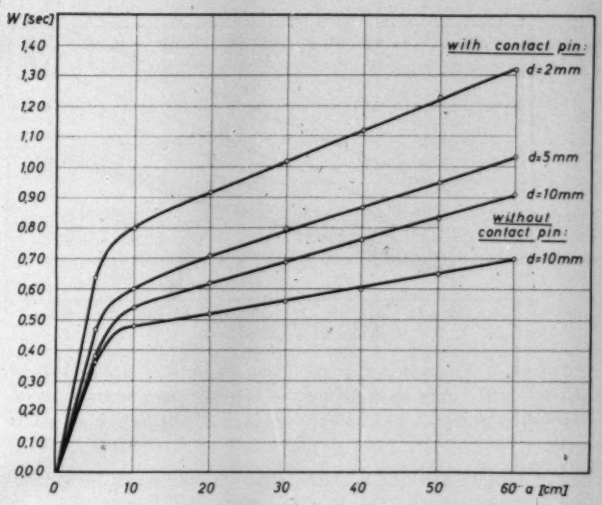


FIGURE 16. Dependence of the Time Required for the Distance Moved on the Diameter of the Target.

have been obtained by experiments.

Within the interval of $2 \leqq z \leqq 10$ the functions of

$$a(z) = a_1 z^2 + a_2 z + a_3$$

$$b(z) = \frac{b_1}{z} + b_2 z + b_3$$

are continuous, monotonously declining and clearly determined. On the basis of the known functional values for $a\ (z)$ and $b\ (z)$ the constants a_1, a_2, a_3 and b_1, b_2, b_3 may clearly be calculated.

Starting from these functions, we calculated the general equation in which the equations quoted under b, c, and d are included as exceptions. When the constants are incorporated, the following general equation will result:

$$y = z^2 \times 0.000045x - z(0.000915x - 0.00317) + \frac{0.6385}{z} + 0.01205x + 0.371$$

z = diameter of the target in mm
x = distance moved in cm
y = time required for the distance moved in sec.

By means of this equation any time required for distances from 10 to 60 cm and targets from 2 to 10 mm in diameter is clearly determined. By inserting z and x, it is possible to calculate for a set of curves the points within the system of coordinates. In Figure 17 the result is shown graphically. So far, the experiments give no hint as to the extent to which extrapolated values in their relationship to greater distances and smaller or greater diameters of the target match the actual conditions, but it is certain that the results of the application of the general functional equation for distances smaller than 10

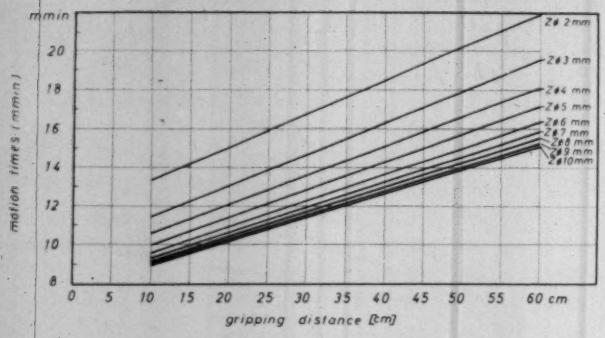


FIGURE 17. Dependence of the Time Required for the Distance Moved on the Size of the Target with Gripping Distances of between 10 and 60 cm.

cm in length are not correct, since there exists no linearity in this field.

When comparing the time values for distances moved of the various elemental time systems with the results of our experiments, an interesting outlook on the degree of validity of the elemental times will result. Besides the curves developed by us and taken over from Figure 16, the following curves are plotted in Figure 18:

A. *MTM System*

1. *Mc*
2. *Mc* + *P* (2 *Sd* for tolerances smaller than 0.8 mm)
3. *Mc* + *P* (1 *Sd* for tolerances from 0.8 to 12.7 mm)

B. *Work Factor System*

4. *SD*-motion (tolerance $16 \leqq d < 50$ mm)
5. *SD*-motion (tolerance 9.8 mm)
6. *SD*-motion (tolerance 4.8 mm)
7. *SD*-motion (tolerance 1.8 mm)

C. *BMT System*

8. *MCV*
9. *MCV* + precision factor 12.7 mm
10. *MCV* + precision factor 6.3 mm
11. *MCV* + precision factor 1.6 mm

Of these four experimental curves and of the 11 reference curves those tabulated at the top of the next page should be compared.

When looking at the first group we shall notice that the values of MTM for a *Mc* motion over small distances are clearly below, and over greater distances above, the 10 mm curve (without contact pin) plotted on the basis of our experiments. The point of intersection of both curves lies at a distance of about 33 cm. With the MTM curve the factor for the distance moved is considered to a higher degree than found necessary in our experiments.

For shorter distances (below 25 cm) the WF curve and the MTM curve are almost identical, i.e. the time values of the Work Factor system are shorter than the values found out in our experiments. From a distance of 25 cm the WF curve for *SD* motions runs almost parallel with ours, the WF time values being about 1 mmin smaller.

(Continued on page 195)

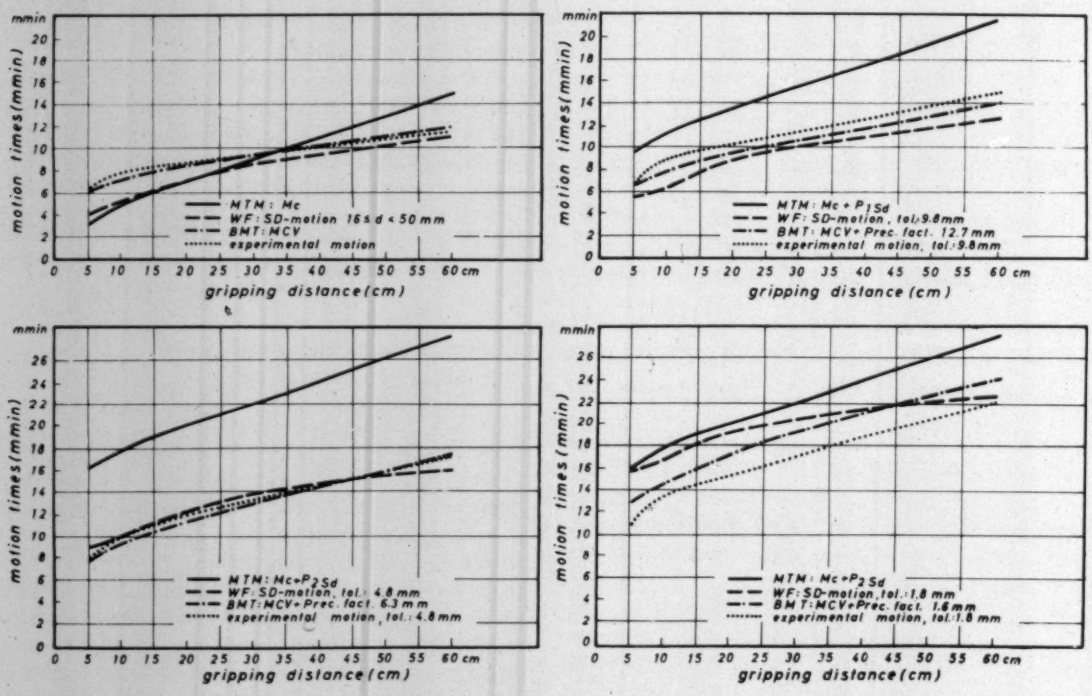

mmin
motion times (mmin)
gripping distance (cm)
MTM: Mc
WF: SD-motion 16 ≤ d < 50 mm
BMT: MCV
experimental motion
MTM: Mc + P1 Sd
WF: SD-motion, tol.: 9.8 mm
BMT: MCV + Prec. fact. 12.7 mm
experimental motion, tol.: 9.8 mm
MTM: Mc + P2 Sd
WF: SD-motion, tol.: 4.8 mm
BMT: MCV + Prec. fact. 6.3 mm
experimental motion, tol.: 4.8 mm
MTM: Mc + P2 Sd
WF: SD-motion, tol.: 1.8 mm
BMT: MCV + Prec. fact. 1.6 mm
experimental motion, tol.: 1.8 mm

FIGURE 18. Relationship between the Time for the Distance Moved and the Diameter of the Target According to the Results of the Experiments and the Various Predetermined Elemental Time Systems.

INSTITUTE INTERESTS

Individuals, chapter officers, institute officers and others are invited to become primary reporters and send in interesting highlights on local, national and international events. The principal criterion is that the item be current and of general interest. Since publication space represents an investment of your funds, please help us avoid "wordy stories." Material can best be handled if it is typed and double-spaced. Pictures to accompany these notices—or just good pictures with explanatory notes are welcomed. Send the material to Professor Wilson J. Bentley, School of Industrial Engineering and Management, Oklahoma State University, Stillwater, Oklahoma. If you forget this address, send it to the JOURNAL *Office in Atlanta, and I will get it.*—EDITOR.

AIIE GENERAL NEWS

There are now more than 10,000 members on the AIIE rolls!

• • •

A task force, under the capable chairmanship of Frank Maggio, has been organized to develop better ways of processing the growing amount of work in the AIIE office. Composed of volunteer members from the Long Island and the Metropolitan New York Chapters, the group has embarked upon an Industrial Engineering survey of the operating procedures in the Institute office. The report on the first phase (handling of membership applications) has been submitted to the Executive Secretary. Recommendations on other phases will follow. This project is scheduled for completion during the summer months.

• • •

The Columbia Basin Chapter in the State of Washington has become the 114th AIIE Chapter. George A. Fox is the president pro-tem. Nine new organizations joined the chapter roster during the past ten months.

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Three of our chapters are located beyond the boundaries of the Continental United States. The term "national" in reference to our organization, its programs and activities, is obviously inappropriate. Consequently, our "National Officials" have become "Institute Officers"; "the National Office" is now "Institute Office"; etc.

Constitution and manuals as well as all other written and oral communications will gradually follow suit in similar adjustment of their terms. Help by revising your chapter's or committee's phraseology accordingly.

STUDENT CHAPTERS

The Texas Technological College's Student Chapter was host to approximately 100 senior and student members on March 8 to hear President Alex Rathe speak on the subject, "Industrial Engineering—From Apprentice to Senior Partner in the Engineering Profession." At their April 4 meeting this chapter had Industrial Engineer Joe H. Kehlbeck of General Electric talk on the subject, "Value Analysis."

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The Oklahoma State University Student Chapter was host to the Tulsa, Oklahoma City, and Wichita Senior Chapters at a meeting on March 10. President Alex Rathe spoke at the meeting. The Oklahoma City Chapter awarded their "Outstanding Junior Industrial Engineer" award to Donald Reynolds. The Tulsa Chapter gave its "Outstanding Senior Industrial Engineer" award to Glen Dale Farquharson.

PERSONALITIES

WYLLYS G. STANTON

This letter was received by the Institute Office. We join the many friends of Mr. Stanton in wishing him a speedy recovery.—EDITOR.

April 21, 1961

Dear Mr. Lange:

It just occurred to me that perhaps many of the members of AIIE might appreciate hearing of the serious accident in which Professor W. G. Stanton was recently involved. Mr. Stanton was driving from Huntsville, Ala., to Tuscaloosa last Tuesday evening when he failed to negotiate a curve and went down a forty foot embankment. He lay in the ditch seriously injured from about 7 p.m. until shortly after 10 p.m. when he finally succeeded in attracting the attention of a passer-by with his flashlight.

Mr. Stanton sustained a broken hip, a cracked pelvis, and severe head lacerations. He is doing as well as can be expected but will be incapacitated for a number of months.

His present address is Room 721, Druid City Hospital, Tuscaloosa, Alabama, and his home address is 10 Fairway Drive, Tuscaloosa.

Sincerely,

GEORGE C. K. JOHNSON
Professor and Head
Department of Industrial
Engineering

• • •

AWARDS

The 1961 Gilbreth Medal awarded by the national office of the Society for the Advancement of Management for contributions in the field of Industrial Engineering was awarded to Gerald Nadler, professor of Industrial Engineering and chairman of the department of Industrial Engineering at Washington University.

The award was presented at the Annual Management Engineering Conference held in New York City April 6 and 7, a meeting sponsored by the management division of the American Society for Mechanical Engineers and the Society for the Advancement of Management.

The Gilbreth Award is given annually by the Society for the Advancement of Management in honor of Frank (now deceased) and Lillian Gilbreth, husband and wife who were pioneers in the field of motion and time study and other phases of Industrial Engineering.

The medal is given for "distinguished service to the Industrial Engineering movement in the motion study or motion and time study fields." Professor Nadler was cited for research in the concepts of motion and motion patterns and research expanding the horizons of motion study and Industrial Engineering; for development of new concepts in studying work resulting in the "work design" approach; for preparing books to disseminate the research

and educational philosophies he developed; and for the international and national impact of his communications on the appreciation of Industrial Engineering philosophies.

Professor Nadler has been a leader in research leading to development of techniques in work design, a procedure for applying work principles which will result in the best possible pattern for producing work to be done.

He joined the Washington University faculty in 1949 and holds the bachelor and master of science degrees and the doctor of philosophy degree from Purdue University.

• • •

Orlando J. Feorene, an Industrial Engineering supervisor at the Kodak Park Works of Eastman Kodak Company, has been named the winner of the Outstanding Alumnus Award given by an Ohio State University engineering group.

This award is made annually by Texnikoi, an honorary activities fraternity in the college of engineering at Ohio State. The award recognizes a young engineering alumnus for outstanding achievement in engineering as well as participation in community activities.

Mr. Feorene received the award April 28 at the Eighth Annual Conference of Engineers and Architects at Ohio State University, Columbus, Ohio.

He is an alternate member of the board of directors and of the executive committee of the Engineers Joint Council, a member of the board of directors of the Rochester Engineering Society and an active AIIE member.

As a member of Tau Beta Pi, national engineering society, Feorene serves as a counselor to undergraduate engineering students at the University of Rochester. He has also participated in a number of youth activities in the Rochester area.

AIIE'S NEW PRESIDENT

JACK F. JERICHO

Jack F. Jericho is presently Superintendent of Work Analysis at United Air Lines in Chicago, Illinois. For the past fourteen years, he has served in many capacities and, since 1954, has been in top administrative Industrial Engineering positions. Prior to 1947, when Mr. Jericho started his career with United, he served as Plant Industrial Engineer for the Graver Tank and Manufacturing Company in East Chicago, Indiana, for four years.

JACK F. JERICHO

In his earlier years, prior to the war, he held several key positions in various phases of Industrial Engineering with Carnegie Illinois Steel Corporation in Gary, Indiana. Upon completion of his university work at Northwestern University and Gary College, Mr. Jericho started his career with Baer Brand Hosiery Company.

In addition to his formal education, he has taken post-graduate work in Quality Control at the University of Colorado and has participated in United Air Lines' Executive Development Program at the University of California in Berkeley.

Mr. Jericho has been very active in lecturing to various Industrial Engineering and SAM chapters and has participated in several Industrial Engineering conferences throughout the country. He has particularly stressed the new concepts and modern image of the Industrial Engineer. He is extremely dedicated to making every contribution possible to furthering the recognition of Industrial Engineering as a profession.

Mr. Jericho has had a very active career with the Institute. During the past two years he has served as the Executive Vice President and, previous to that time, he was Vice President of Region X, which covers all of the states in the western part of the country. He has been very active in organizing new chapters and has spearheaded the complete reorganization of the AIIE.

He is considered one of the leaders in the field of Industrial Engineering and has made many significant contributions in his long and successful career.

Some personal characteristics are . . .

. . . Jack Jericho is perpetual mental motion, sprinkled with a special exhilarating charm. Some friends maintain he invented the panic button, others say he was merely tutored by its inventor. In either case, he rarely stays in one place very long; but, while he's there, his presence is appreciated and something will be accomplished.

. . . Jack and his wife have relocated four times in the last ten years and, due to speaking engagements, society affairs, or job requirements, he has been on the road every time. His wife, Jo (a tournament bowler), insists that he has not met his apartment neighbors yet, but knows half of the cab drivers and barbers from coast to coast.

. . . Jack's readily excitable characteristic is a reflection of his intense interest and dedication to everything he tackles. His exceptional memory and engulfing interest have made him the curbstone expert in disputes such as: "Was Dempsey ever knocked out?"; "Who was the first mayor of East Tin Cup?"; and "How should I answer a five no-trump opening?".

. . . While his interests are widespread, he is especially interested in athletics (primarily football and baseball—where he occasionally advises his pal, Lou Boudreau, and several "amateur" umpires). Also, he has a profound interest in people—as people. With his human, likable, easy-to-know manner, Jack has more friends than many politicians. Throughout his long upward climb to national prominence, he has retained friendships often bypassed by others. In spite of his keen vision and insight, he has not yet realized that he has become a big man and most of his friends are certain he never will.

AIIE is most fortunate to have a man like this among its senior officers.

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FINANCIAL STATEMENT OF AIIE

Cash records of AIIE have been audited by Ernest J. Feleppa, CPA, for the period beginning October 1, 1959 to September 30, 1960. For the information of all members, the audit is presented.

Exhibit A

RECONCILIATION OF BANK FUNDS SEPTEMBER 30, 1960

Funds on Deposit—October 1, 1959		
The Huntington National Bank—general account		$ 31,742.01
The Huntington National Bank—office account		354.36
Buckeye Federal Savings & Loan Association		10,000.00
The Columbus Savings & Loan Association		3,000.00
Dollar Federal Savings & Loan Association		1,853.73
First Federal Savings & Loan Association		1,000.00
Franklin Federal Savings & Loan Association		9,453.37
Ohio Federal Savings & Loan Association		5,000.00
Park Federal Savings & Loan Association		10,000.00
The People's Savings Association		1,000.00
Scioto Savings Association		500.00
Standard Savings & Loan Company		6,659.16
State Savings		1,000.00
Total on deposit October 1, 1959		$ 81,562.63
Gross receipts—per Exhibit B		151,471.46
Total available funds during period		$233,034.09
Gross disbursements—per Exhibit C		191,906.22
Balance of funds—September 30, 1960		$ 41,127.87

RECONCILIATION OF CASH FUNDS
SEPTEMBER 30, 1960

Chase Manhattan Bank	$ 16,172.53	
Less—Accrued traveling expenses payable	2,107.77	$ 14,064.76
Bowery Savings Bank		9,004.37
Emigrant Industrial Savings Bank		9,004.37
Union Dime Savings Bank		9,004.37
Cash on Hand (Petty Cash Fund)		50.00
Total cash funds		$ 41,127.87

Exhibit B

STATEMENT OF CASH RECEIPTS
Fiscal Year ended September 30, 1960

Cash Receipts:		
Dues:		
Member	$ 37,309.27	
Associate	40,871.15	
Affiliate	7,942.42	
Student	3,861.00	
Chapter	24,244.18	
Members at Large	1,348.29	
Total dues		$115,576.31
Other Income:		
Application fees	$ 8,580.00	
Conference proceedings	4,432.57	
Insignias	1,777.96	
Journal	11,406.17	
Mailing list	3,194.12	
Membership kits, books, etc.	1,334.09	
Sale of equipment	784.00	
Miscellaneous	430.61	
Dallas Convention	1,687.06	
Total other income		33,626.58
Interest Income:		
Savings bank funds		2,268.57
Gross receipts		$151,471.46

Exhibit C

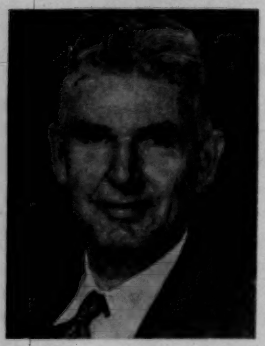
STATEMENT OF CASH DISBURSEMENTS
Fiscal Year ended September 30, 1960

Cash Disbursements:			
Salary and payroll taxes		$ 47,106.94	
Less—Payroll taxes withheld—net		882.72	
Net salaries and payroll taxes			$ 46,224.22
Rent—Columbus, Ohio		$ 4,262.50	
New York, New York		149.50	4,412.00
Communications:			
Postage		$ 7,023.21	
Telephone		1,771.83	8,795.04
Office supplies and stationery			9,118.01
Office maintenance & expenses			579.36
Publications, printing, and engraving			$ 8,048.12
Journal publication			32,554.14
Travel and expenses:			
Executive Secretary		$ 1,442.96	
Officers		22,576.48	
Directors and Committee Chairmen		3,257.39	27,276.83
Refunds:			
Rebates		$ 33,421.42	
Dues and fees		771.11	34,192.53
Conference and convention expenses			1,214.70
Chapter expansion and Membership processing			4,256.42
Engineers Joint Council membership			1,932.00
Insignias and certificates			1,860.01
Mailing list rental			697.77
Professional services			1,853.20
Business administration			1,314.62
Insurance			411.97
Bank charges			110.23
Ballots			1,105.07
Columbus, Ohio, office			51.75
New York, New York, office			150.00
Temporary office help			170.34
Office equipment			1,127.61
General expenses			332.99
Sub-total			$187,788.93
Other Deductions			
United Engineering Center Reserve Fund:			
Rent—New York City office		$ 801.00	
Office equipment		790.69	
Moving expense (Columbus to New York City)		1,225.60	
Total chargeable to reserve fund			2,817.29
Reserve Accounts:			
Detroit Conference		$ 1,000.00	
Region III Conference		300.00	
Total for reserve accounts			1,300.00
Total disbursements			$191,906.22

On September 29, 1960 a new bank account was opened with the Irving Trust Company in which income from dues amounting to $5,913.00 and miscellaneous income amounting to $423.25, or a total of $6,336.25 were deposited to September 30, 1960. These receipts are applicable to the fiscal year beginning on October 1, 1960 and are not included in the acocunting data for the fiscal year ended September 30, 1960.

FELLOWS OF AIIE

RALPH M. BARNES



RALPH M. BARNES

Ralph M. Barnes is Professor of Engineering and Production Management at the University of California, Los Angeles. An engineering graduate of West Virginia University, he received his M.S. and Ph.D. degrees from Cornell University. He held the Du Pont Fellowship in Engineering while at Cornell. He has been associated in engineering capacities with such organizations as: Bausch and Lomb Optical Company, the Gleason Gear Works, Eastman Kodak Company of Rochester, New York and Kodak Limited of London. Professor Barnes was formerly Professor of Industrial Engineering at the University of Iowa. He originated the Iowa Management Course and served as its director from 1939 to 1948.

In 1945 while on leave from the University of Iowa, Professor Barnes helped develop the Industrial Engineering Center of the Armstrong Cork Company in Lancaster, Pennsylvania, and served as its first Director.

During the summer of 1950 he served as Consultant for the Industrifor Bundets Rationaliseringskontor A/S (Association of Norwegian Industries), and the Association of Swedish Industries. He directed a Management Course in Oslo and a similar course in Stockholm for these organizations. Over one hundred engineers and managers attended these two courses.

In 1956 he served as Consultant to the Government of Spain in the establishment of the School of Industrial Administration in Madrid. During the summer of 1958 he served as Consultant for Fabrica Uruguaya de Neumaticos S.A., Montevideo, Uruguay. Also, he gave lectures at the College of Engineering in Montevideo and at the School of Business Administration in Sao Paulo.

Professor Barnes had assignments during the summers of 1957 and 1959 with the Central Institute of Productivity of Mexico which took him to Mexico City, Guadalajara and Monterrey. While on a sabbatical leave of absence from the University of California during the fall of 1959, Professor Barnes visited research laboratories in London, Cambridge, Birmingham, Leiden, and Dortmund. He gave lectures in several European countries and also undertook a short assignment for the School of Industrial Administration in Madrid, Spain.

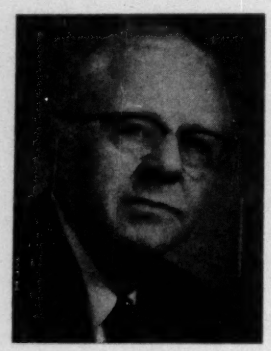
During the summer and fall of 1960 he assisted in establishing a full-time nine month Post Graduate Industrial Engineering Program in Belgrade, Yugoslavia; and worked out a series of seminars in Industrial Engineering to be given over the next two years in Costa Rica.

Professor Barnes, besides being a fellow of the American Institute of Industrial Engineers, is a member of the American Society of Mechanical Engineers, the Society for the Advancement of Management, and the American Association for the Advancement of Science. He holds membership in the Industrial Management Society and the American Society for Engineering Education. Currently he is a member of the Advisory Committee of the Management Division of the American Society of Mechanical Engineers. He is also a member of Tau Beta Pi, Sigma Xi, Sigma Iota Epsilon, Pi Tau Sigma, Alpha Pi Mu, and Beta Gamma Sigma.

In 1941 he was awarded the Gilbreth Medal by the Society for the Advancement of Management for outstanding achievement in the field of management; and then, in 1951 he was given the SAM Industrial Incentive Award for his work in the field of Work Measurement and Financial Incentives.

Professor Barnes is the author of several books on engineering and production management, including: *Motion and Time Study*, Fourth Edition, *Work Measurement Manual*, Fourth Edition, *Industrial Engineering and Management*, *Work Methods Manual*, and *Work Sampling*, Second Edition. His books have been translated into Spanish, French, Italian, and Japanese.

H. G. THUESEN



H. G. THUESEN

Nearly 36 years ago Oklahoma A and M College, now Oklahoma State University, established one of the earlier Industrial Engineering curricula. The man chosen to supervise this new curriculum was a young General Electric engineer, H. G. Thuesen. Thuesen had earned a B.S. in mechanical engineering with an Industrial Engineering option at Iowa State College in 1921. At Iowa State Thuesen studied under Professor J. O. Keller who was said to be the first recipient of a college degree in Industrial Engineering. Thuesen later returned to the same institution to receive his master's and professional engineer's degrees.

Thuesen soon developed the Industrial Engineering Department into an active and progressive organization. Among his early personal accomplishments was the application of the principles of motion economy to the petroleum-producing industry —an area which had been thought too irregular for valid analysis. Thuesen's new techniques in this field were formulated under the name "Job Design."

Furnished with a basic idea, Thuesen and one of his first graduates, G. A. Hale, designed and built the first parking meter in 1931. Thuesen served as technical advisor to the company that made the first installation of commercial parking meters in Oklahoma City in 1935. Last year in the United States alone, almost two million parking meters collected well over $100,000,000 for some 4,000 municipalities.

In 1937, Thuesen organized one of the earliest management conferences in industrial relations in the southwest. The success accorded these initial industry conferences prompted the establishment of a large and expanding program of courses offered for the benefit of the managing personnel of industry in Oklahoma and the surrounding area. Industrial leaders, consultants and outstanding educators from all over the United States are brought in to lead these conferences.

During the war years, when he served as acting Dean and Assistant Dean of Engineering for a period of six years, Professor Thuesen developed an automatic time recorder for research in motion economy. The recorder, used extensively by the University of Iowa and the Western Electric Company, facilitated the collection of data accurate to 0.0001 of a minute and thus opened up new fields of research on human motion. For his accomplishments in the development of research devices, Thuesen received the Academy of Time Award from the Benrus Watch Company both in 1947 and 1948.

Engineering Economy, Thuesen's book on economic analysis, first published in 1950 and revised in 1957, has been widely adopted in engineering colleges and in industry in the United States and Canada. An innovation in this text is Thuesen's system of mnemonic notation which combines factor designations with factor values in order to reduce the time and labor required in economic analyses. There are indications that these innovations may eventually gain general acceptance.

Professor Thuesen has been the Chairman of the Industrial Engineering Division of the American Society of Engineering Education; Vice President of the Southwest Region of the AIIE

and a member of the editorial board of the *Journal of Industrial Engineering*. In 1954, AIIE conferred the rank of Fellow of the Institute on Thuesen.

During his career, Professor Thuesen has served as consultant to numerous firms. Among those with whom he has had professional contacts are General Electric, Western Electric, Westinghouse, Phillips Petroleum Company and the Magee-Hale Park-O-Meter Company.

Thuesen has an extensive list of bulletins and articles published in various journals and he still contributes regularly. He has long been a vocal advocate of professional engineering registration and is active in both the Oklahoma Society and the National Society of Professional Engineers.

In 1957 Professor Thuesen, after 32 years as department head, asked to have more time to write, teach, research, think and tinker. He turned over the department headship to one of his students and a colleague of many years, Wilson J. Bentley. Thuesen is now more productive than ever. He also, as he says, has more freedom to count the days left before spending his summers traveling and living in his summer home in Frisco, Colorado.

As impressive as these acomplishments may be, Professor Thuesen's greatest contribution lies in the effect he has had on students. Nearly seven hundred Industrial Engineers who have received graduate and undergraduate degrees at Oklahoma State University and many other students have been fortunate enough to study under his direction. The feeling among his students is the highest compliment a teacher can receive: That is, "If you haven't had a class under Professor Thuesen, then enroll in one. It doesn't make much difference what the subject is because the contact with him is well worth the time and effort." The achievements of his students offer ample evidence to the validity of Professor Thuesen's credo: "Education is society's most profitable activity."

PROFESSIONAL SERVICES AND PLANNING PROGRESS REPORT, 1960-61

MORLEY H. MATHEWSON, *Vice President*

The year 1960-61 saw the completion of the first year of the new AIIE organizational concept. Professional Services and Planning, as one of the major segments of the newly designed organization, is dedicated to its role of forward planning for the Institute. Each department is concerned with the development of programs which will lead to the continuous upgrading of the profession of Industrial Engineering.

In 1960-61, the first year Professional Services and Planning has existed within AIIE....

....a total of *55* projects have been active.

....a total of *115* members and fellows of AIIE have participated.

OFFICE OF THE VICE PRESIDENT

PROFESSIONAL RELATIONS NEWSLETTER

This publication has been discontinued. News is now disseminated to the members through the Journal "Institute Interests" section and to AIIE Officers through the President's newsletter, "Intercom." Officers of Professional Services and Planning will prepare activity reports for the Journal in accordance with the following schedule:

Officer	*Journal Issue*
Vice President	May-June
Professional Relations Director	September-October
Research and Development Director	November-December
Professional Development Director	January-February
Long Range Planning Director	March-April

PROFESSIONAL RELATIONS COMMITTEE

With the adoption of the new AIIE organization this committee was abolished. The Institute president is now authorized to appoint up to a 20 member advisory council of distinguished Industrial Engineers that will report to his office. The council is to serve as a sounding board and provide guidance to the president.

AIIE-ASEE SYMPOSIUM

Arrangements were made at the 1960 Dallas Convention to hold a joint AIIE-ASEE Symposium on May 10, 1961, one day prior to the start of the AIIE Convention in Detroit. The theme of the symposium, "Industrial Engineering in 1975," was selected to provide the vehicle to get a group of distinguished educators and practitioners to do long term thinking on the subject. Papers presented at the symposium will form the basis for a publication that will be handled by AIIE.

JOINT AIIE-AMA RESEARCH STUDY

Working in cooperation with John Enell, Director of the Information Service and Survey for the American Management Association, a joint AIIE-AMA research program on Industrial Engineering has been initiated. Alex Rathe has been asked to head the program which is expected to involve over 5,000 companies throughout the United States. It is hoped that many of these companies will agree to answer detailed questions regarding their Industrial Engineering activities.

LONG RANGE PLANNING

MANAGEMENT AND INDUSTRIAL ENGINEERING SYMPOSIUM

Plans have been formulated to hold a management and Industrial Engineering symposium to discuss "Industrial Engineering in Today's Society." The idea was to have 10 Industrial Engineers in education, government, and industry meet with 10 company presidents to discuss the subject. A formalized program was presented at the Detroit Convention.

MANAGEMENT ENGINEERING AND SCIENCES STUDY TASKFORCE

A taskforce to study management engineering and management sciences has been organized under the chairmanship of Austin Weston. This subject was also discussed at the Industrial Engineers' and Company Presidents' meeting and at the AIIE-ASEE Symposium.

NEW AIIE ORGANIZATIONAL MANUAL

A new AIIE Organizational Manual containing a complete set of organization charts and position descriptions was completed by Warren Mellin and subsequently approved at the December 1960 Board of Trustees meeting.

The organization charts will be revised annually to reflect the changes in administration, but the job descriptions will be changed only as the need occurs to keep the information meaningful and correct. Every AIIE Institute officer, director, committee chairman, and chapter president is urged to read the complete set in order to fully comprehend the new organization.

PAST PRESIDENTS TO PROMOTE INDUSTRIAL ENGINEERING

As a result of a study made by Donald Malcolm, Warren Mellin, and Morley Mathewson the recommendation to use past presidents to promote the Industrial Engineering profession was approved by the Board of Trustees in December 1960. In essence, the past president will contact a top executive of a major organization to discuss modern Industrial Engineering. Reports of these meetings will be presented each year to the current president.

PROFESSIONAL DEVELOPMENT

SCHOLARSHIP GRANTS FROM FORD FOUNDATION

An AIIE taskforce consisting of Herb Jacobs, Morley Mathewson, Andrew Schultz and Robert Lehrer has met with members of the Ford Foundation to request the establishment of special scholarship grants for advanced education and research study in Industrial Engineering. At the conclusion of this initial meeting with the Foundation, AIIE was asked to prepare a position paper describing the scope and interest of Industrial Engineering indicating the contributions Industrial Engineering can make that cannot be better made by Business and Industrial Administration.

The preparation of this paper is moving forward, and a series of committee meetings will be necessary before a final proposal is submitted. In the meantime, the Ford Foundation has agreed to open their Teachers Fellowship Program (previously restricted to Business Administration and Economics) to Industrial Engineering.

PROFESSIONAL RELATIONS

CIVIL SERVICE INDUSTRIAL ENGINEERING CLASSIFICATION

In July 1960 the Civil Service Commission published a set of position descriptions for Industrial Engineers which now provide a comprehensive and definitive classification. While this classification only applies to Industrial Engineers in the federal service, it will become an important reference for defining the duties and activities of all Industrial Engineers.

Because of the effect that such a classification will have on the profession in general, AIIE has long been interested in discussions related to Industrial Engineering in the Federal Service and has taken an active part in providing guidance and counsel to the Commission.

CANADIAN AFFAIRS

All of the material relating to preparing Regional Boundaries in Canada has been submitted to Jack Jericho. Problems of member ship qualifications now being reviewed by members of the International Relations Committee stem in part from differing engineering curricula taught in Canada, and the fact that many Canadian engineers have European educations.

RESEARCH AND DEVELOPMENT

MAJOR PROJECTS

Each director in the Research and Development organization has been asked to prepare a paper dealing with a major topic of interest in his area of responsibility. These papers were presented at a one day symposium prior to the Annual Meeting and will be published by the Institute.

RESEARCH AND DEVELOPMENT IN THE FUTURE

A meeting of the Research and Development Officers has been called to discuss the entire Research and Development program of the Institute. This meeting in May 1961 launches a comprehensive survey of the whole field of Industrial Engineering in terms of its substance, the present state of the art, the on-going research and near and long term research needs.

PROFESSIONAL INTERESTS

THE AIIE AND THE ENGINEERING SOCIETIES LIBRARY

The American Institute of Industrial Engineers will share, with ten other engineering societies, the privileges of use of the Engineering Societies Library. This is new for the AIIE, but old for some other societies. The Engineering Societies Library (ESL) is nearly fifty years old, but its roots go back further for it was originally formed by combining the separate libraries of the ASCE, AIME, ASME, and AIEE which were started shortly after these societies were established in the years from 1852 to 1884.

The relatively unorganized separate collections were combined, classified and indexed, and duplication eliminated. This resulted in savings for the societies and a greatly superior library, one that is recognized as the oustanding engineering library.

PUBLICATIONS FROM AIIE

The societies moving into the United Engineering Center may add their engineering books and technical papers to the ESL. The Library hopes to get all AIIE technical engineering publications currently and automatically. With the help of the AIIE and other societies in the UEC, the ESL can be further strengthened as the library of the engineering profession.

The Library is a department of the United Engineering Trustees, Inc. The Library Board is composed of representatives appointed by the societies which maintain the Library.

COLLECTION AND STAFF OF ESL

The ESL has a selected collection of 180,000 volumes, 27,000 maps, 10,000 indexed bibliographies, all major and many minor indexing and abstracting services in engineering, physical sciences, and technology, and many thousand unpublished papers of its supporting societies. This means that it has some six miles of books to move into the UEC. The Library is currently receiving 3,400 periodicals and other serial publications from 45 countries, in 21 foreign languages as well as in English.

In addition to collecting extensively, but selectively, engineering publications of all types on a world-wide basis, the ESL maintains extraordinarily complete files of all technical publications and papers of its supporting societies. Its collection of these unpublished papers is particularly important, for many of them are manuscript copies not elsewhere available, not even in the societies' own files. The Library has special card indexes to some sets of these publications. It also, in some instances, cooperates with the editorial staffs of its supporting societies in the preparation of published indexes.

After preprint and published stocks of their publications are exhausted, the societies refer inquirers to the ESL for photoprint or microfilm copies. Often this is done simply by transferring the inquirer's letter or order directly to the Library. This seems to be the best way to serve with the least possible delay.

During the past year 9% more volumes were added than in the previous year. The accessions rate is 40% greater than three years ago. The Library has a staff of 30 persons, half are clerical, and half are trained librarians with technical training and experience, and knowledge of at least a dozen foreign languages.

SERVICES AVAILABLE

The services of the ESL include a reading room open six days each week all year, and five nights a week except during the summer.

Thousands of requests from members for brief information which can readily be located are answered without a charge. For members and others requiring extensive information, literature searches and bibliographies are made, for a fee, to the specific requirements of the inquirer. The service ranges from recommending some books on a specific subject to the preparation of comprehensive annotated bibliographies of books, articles, and reports. Searches are also made for disclosures related to patents. All search work is kept confidential.

The Library Staff also prepares bibliographies on subjects of general engineering interest. These may be purchased by anyone. A list is available on request.

Translations of engineering and technical articles are made from all languages into English by "consultant" translators who are familiar with engineering. All translations are reviewed by a

member of the Staff of the Library to assure accuracy of translation and the quality of the English.

Photoprint and microfilm copies of material in the Library are made on request.

In each recent year about 700 engineering books have been reviewed by the Library Staff. The reviews are made available to the editors of the journals of the societies which support the Library. The editors select and publish those they believe to be of interest to their members and other readers so they may learn about recent books in their field. Most of the books reviewed as well as others in the Library may be borrowed by members of supporting societies.

The aforementioned services, except loans of books to members, are available to anyone. They are used by engineers, scientists, technologists, and industry in this country and throughout the world.

Editors of engineering society publications make frequent use of the ESL in their work.

In each recent year many hundreds of letters have been referred by the headquarters staffs of supporting engineering societies to the ESL for reply, thus saving the societies' time and money.

THE ESL AND THE ENGINEERING INDEX

Through cooperation between these two separate organizations, engineers and industry have services unmatched elsewhere in the world, i.e. an extensive index published on cards and also in an annual volume which covers the contents of the largest engineering library in this country, intended primarily to serve graduate and practicing engineers.

All publications received and retained by the ESL, including the 3,400 currently received periodical and other serial publications, as well as a substantial number of bulletins, reports, symposia, and unpublished papers are made available to the Staff of the Engineering Index, Inc. From these publications 33,000 articles and other items were indexed in 1960. Each reference is annotated and all are published in a daily card service and subsequently in a cumulated annual bound volume. The card service is also available on a weekly basis in any one or more of the 255 subject divisions. Inquiries and subscriptions for the EI services should be addressed to the Engineering Index, Inc., which now is at 29 West Thirty-Ninth Street, New York 18, New York, but which will move into the United Engineering Center building in the fall of 1961, as will also the AIIE and the ESL.

Inasmuch as all indexed material is retained by the ESL, there need be no question about where to find the original of any articles indexed in the EI. The articles may be read at the ESL, which is open to anyone, or a photoprint or microfilm copy may be ordered.

GROWTH OF USE OF ESL

The ESL is a busy information center which becomes busier each year. Last year the use of the Library increased 14% over the previous year. Use of the Reading Room has remained relatively constant since its peak during the depression years of the 1930's. On the other hand non-visitor use of the Library by mail, telephone, and telegraph increased 26% in the last year; 176% in the last ten years. The total number of those served by the ESL was nearly 60,000, of which 68% did not visit the Library. A sampling of 15% of last year's correspondence showed users in 31 foreign countries, and in 47 of the 50 states of the USA.

The ESL is used by individuals and organizations. Of the latter, those with libraries of their own are among our greatest users. Last year on 6,334 orders, 87,500 photoprints were supplied —an increase of 23%; 484 microfilm orders were filled—up 25%; 168 literature searches were made—up 29%; 715,000 words were translated from a dozen foreign languages—up 84%; 2,270 books were loaned to members—up 13%; and 24,700 telephone inquiries were answered—up 36%. Income from the paid services of the ESL increased over 40%. Last year the Founder Societies' direct contribution to the Library amounted to about 58% of its total income. Most of the other 42% came from charges for services, and smaller amounts from endowments, royalties, and contributions from other societies.

A free information folder about the Library and its services, and a list of available bibliographies are available on request to the Engineering Societies Library, 29 West Thirty-Ninth St., New York 18, New York. Ralph H. Phelps is the Director of the United Societies Library.

SENIOR CHAPTER NEWS

CENTRAL INDIANA CHAPTER

The Community Service Committee, composed of H. T. Amrine, R. L. Miller and J. W. Barany, has been working closely with the administrative personnel at the Lafayette Home Hospital in an attempt to improve the food servicing department. The following recommendations have been submitted and accepted by hospital staff:

1. The selective menu forms were redesigned in order to facilitate the assembly of the individual trays and to minimize errors.
2. Through the efforts of the head nurses on each floor, the serving schedule was rearranged in order to permit a smoother flow of the food from the kitchen to the patient. After rerouting the food carts, three girls perform the serving task which formerly required five girls.
3. A systematic procedure was established for handling all changes in patient diets and for feeding the critically ill.

The next phase of the project will consist of an analysis of the tray preparation area in the kitchen itself.

CHICAGO CHAPTER

The Chicago chapter presents its Spring Conference on June 15-16. Subjects covered will include: New Developments, New Horizons, New Frontiers and Practical Working Techniques in Industrial Engineering. Edmond A. Wroblewski is chairman of the conference.

CINCINNATI CHAPTER

The Chapter recently sponsored a one day conference on the subject of "Total Systems Concept for Total Cost Control." Speakers were: Roger W. Christian, Associate Editor of Factory Magazine, and Fred W. Thomas, Manager, Business Systems Planning, General Electric Company.

COLUMBUS CHAPTER

The Columbus Chapter of The American Institute of Industrial Engineers has had numerous successful and rewarding programs during the 1960-61 year, under the excellent leadership of its elected officers, who are, Don Worstell, President; Ken Landis, Vice President; John Fortney, Secretary and William E. Thompson, Treasurer.

The regular monthly meetings have been well attended, both by members and guests. Also, an encouraging number of student members have attended these meetings. The guest speakers for these regular monthly meetings have discussed a number of diversified technical subjects. The guest speaker for the September meeting was Doctor Richard Podol, Management Analyst for OMETA, who discussed the subject of "Organization Analysis." Mr. Benjamin W. Neibel, Professor and head of the Industrial Engineering Department at Penn State University, was the guest speaker for the October meeting. Mr. Neibel's topic was "The Need for Industrial Engineering Techniques In Product Engineering." The November meeting was the Fifth Annual Bosses and Top Management meeting in which Mr. J. L. Kerins, Assistant Vice President, General Operating Division, United States Steel Corpo-

ration, discussed, "Industrial Engineering's Responsibility to Management." In December, two meetings were held. Alex W. Rathe, National President of the American Institute of Industrial Engineers, was the guest speaker at one of these meetings. He discussed, "Industrial Engineering's Contribution to Managerial Planning and Control." This meeting was also attended by representatives from the Stark County, Akron, Dayton and Marion Chapters. The second meeting in December was a joint meeting with the Columbus Chapter of the American Society for Quality Control. The guest speakers for the evening were Mr. R. B. Nottingham, Director of Quality Control, and Mr. James Ralph, Quality Control Supervisor in the Fabrication Division of the North Electric Company at Galion, Ohio. The topic which they discussed was "Machine Capabilities." Their discussion offered some advanced techniques for determining practical production tolerances and also a method of predicting a quality level for numerous manufacturing operations. The January meeting was the Annual Ladies Night meeting.

The Columbus Chapter sponsored their annual one day conference on February 25, 1961. The theme of this one day conference was "Overhead Cost Control." The conference presented one of the few opportunities for supervisory and management personnel, along with Industrial Engineers in the Central Ohio area, to keep abreast with new techniques for controlling overhead costs. The conference was conducted this year by H. B. Maynard and Company, Incorporated.

In addition to the above activities, the Chapter has also conducted some special workshop meetings on work sampling and predetermined time data. In January, a plant tour through the Columbus American-Standard Plant was conducted jointly with the local Materials Handling Society.

MIAMI CHAPTER

The Chapter has submitted a formal bid for the 1966 National AIIE Conference and Convention. Plans have been finalized to sponsor an Operations Research Symposium in conjunction with the University of Miami Department of Industrial Engineering.

The Chapter also sponsors an award at the South Florida Youth Science Fair. The award for the outstanding project in the field of Industrial Engineering was given to Bernie Reller of Miami Beach. Bernie's project demonstrated "Automation and the Feedback Principle." It consisted of a small transistorized automobile with electric eye controlled by two beams of light. The car moved along a prescribed path guided by the amount of light projected. The amount of light projected, on the other hand, was automatically controlled by the movement of the miniature automobile. Bernie is 14 years old and is in the eighth grade at Nautilus School. He was awarded a plaque and a slide rule for this outstanding project.

MILWAUKEE CHAPTER

An Industrial Engineering Seminar was co-sponsored by the Engineers Society of Milwaukee and the Milwaukee Chapter of AIIE. The program consisted of four evening sessions of two hours each.

The first two sessions dealt with some new approaches in the use of "Standard Data for Control of Direct and Indirect Labor." Mr. Walter H. Houghton, Chief Standards Engineer, Harley-Davidson Motor Company of Milwaukee, conducted these two meetings.

The third session covered "Unions and Incentives." Mr. Owen Fairweather, Partner, Seyfarth, Shaw, Fairweather and Geraldson, Chicago, Illinois discussed incentive programs, their objectives, installation and control, based on his extensive experience in labor law and negotiations of contract agreements.

The fourth session covered "Preventing Deterioration of Incentive Programs." This discussion was led by Mr. H. B. Rogers, Professor of Industrial Management, School of Business, Northwestern University, Evanston, Illinois.

The Milwaukee Chapter is currently working with members of the Marquette University Engineering Staff toward the goal of establishing an undergraduate program in Industrial Engineering. Recently, the College of Engineering at Marquette submitted a proposed curriculum to the Milwaukee Chapter that will lead to the degree of Bachelor of Industrial Engineering.

SAN ANTONIO CHAPTER

On February 22, the San Antonio Chapter of the American Institute of Industrial Engineers commemorated "Engineers Week."

Dr. Alex W. Rathe, National President of the American Institute of Industrial Engineers addressed the dinner meeting on

Pictured above are: First Row: Elmer Cox, Secretary, San Antonio Chapter; Pat Pape, Industrial Engineering Student, St. Mary's University; Professor Turgot Ozan, Chairman, Department of Industrial Engineering, St. Mary's University; Tony Panza, Industrial Engineering Student, St. Mary's University; Rocky Mogas, Industrial Engineering Student, St. Mary's University. Second Row: Harold M. Scherr, President, The Juvenile Manufacturing Company; Ronald Monford, President, Student Industrial Engineering Club; Paul Juul, Regional Vice President of AIIE; Dr. Alex W. Rathe, President of AIIE, Lt. Col. C. McCredie, President, San Antonio Chapter; Rev. James Young, Dean of Faculties, St. Mary's University; Dr. George B. Kohnen, Dean, School of Business Administration, St. Mary's University; Professor J. M. Youngblood, Treasurer, San Antonio Chapter; Dr. Paul C. Goelz, Graduate Adviser, School of Business Administration, St. Mary's University.

"The Industrial Engineer's Role in Top Management." The meeting was held at the Officers Club of Fort Sam Houston. One hundred and fifteen engineers, educators, and guests attended. Universities represented were St. Mary's University of San Antonio, Texas University of Austin, and Texas A and M University of College Station.

Dr. Rathe spent two days with the San Antonio Chapter discussing problems of chapter administration and development. He conferred with officials of St. Mary's University on the planning and expansion of its department of Industrial Engineering.

Mayor J. Edwin Kuykendall named Dr. Rathe an Honorary Alcalde (Mayor) of the City of La Villita within the city of San Antonio.

The chapter experienced a new stimulus toward professional excellence from the warm, inspiring, and precise counsel of Dr. Rathe.

NASHVILLE CHAPTER

The Nashville Chapter held its fourth annual one day conference on Saturday, February 11, 1961. Over one hundred persons were in attendance to hear speakers discuss "Better Management through Industrial Engineering Techniques." The conference was highlighted by the presence of Past President Frank J. Johnson as keynote speaker, who talked on, "Industrial Engineering. . . . A Complete Shopping Center for Management." John Mahalic, Vice President of Avco Manufacturing Company followed with "Practical Industrial Engineering," and exemplified Industrial Engineering as a broad background leading to virtually any position in staff and operations. Two conferences were then held simultaneously with Robert A. Roth of DuPont discussing a new technique, "Technical Activity Analysis," and Paul Judy of Whirlpool Corporation analyzing "Long and Short Range Cost Reduction Programs."

The luncheon speaker, Dan May, President of May Hosiery Mills, gave an "eye opening" talk based on his recent trip to Russia.

Following the luncheon, a panel consisting of Wayne Hudson, Avco Manufacturing Corporation; Shepherd Swartz, May Hosiery Mills; Ralph Dunckel of Tennessee Polytechnic Institute; and Robert McKinley, Ford Glass, discussed "What Management Expects of Engineers." Many interesting points were introduced concerning education factors and problems which many young engineer's face in industry. At 3:00 two more simultaneous talks were given. Duke Scott relayed his experiences in "Work Simplification, A Management Tool." Serge Birn related his new means of work measurement in an invigorating talk, "Work Measurements in the 60's."

The chapter sponsors two civic events each year. The first, an essay contest, awards a slide rule for the best paper written on a given topic. The second contest awards a plaque to the best Industrial Engineered Junior Achievement Company in the Nashville area.

SYRACUSE CHAPTER

The April workshop on "Indirect Labor Measurement Control Incentives" was attended by over 150 persons. Speakers included: Charles V. Clarke, Robert W. Bosler, and Grover C. Barkdoll (all of H. B. Maynard and Company).

★ ★ ★ CALENDAR ★ ★ ★

May 22–26: **1961 American Society of Tool and Manufacturing Engineers National Convention,** New York Coliseum.

May 25–26: **19th National Meeting of the Operations Research Society of America,** Sheraton-Blackstone Hotel, Chicago, Illinois.

June 5–7: **2nd Annual Manufacturing Supervisions Short Course—Management Games—Statistical Quality Control—Linear Programming,** Industrial Management Department, Auburn University, Auburn, Alabama.

June 5–15: **Short Course on the Mathematical Techniques of Operations Research,** sponsored by Purdue University's Statistical Laboratory and Division of Adult Education, Purdue University, Lafayette, Indiana.

June 5–16: **Operations Research course,** sponsored by the Case Institute of Technology, University Circle, Cleveland 6, Ohio.

June 7–17: **Design of Experiments,** Purdue University, Lafayette, Indiana.

June 11–16: **Conference on Mechanization Policy and Planning,** sponsored by The Industrial Management Center, The Lake Placid Club, Essex County, New York.

June 11–16: **Conference on Capital Expenditure Analysis,** sponsored by The Industrial Management Center, The Lake Placid Club, Essex County, New York.

June 13–16: **Cornell University Industrial Engineering Seminars,** Ithaca, New York.

June 15–16: Chicago Chapter Spring Conference, Palmer House, Chicago, Illinois. Write: Edmund A. Wroblewski, International Minerals and Chemical Corp., Old Orchard Road, Skokie, Illinois.

June 18–23: **Conference on Inventory Planning and Control,** sponsored by The Industrial Management Center, The Lake Placid Club, Essex County, New York.

June 18–30: **Conference on Materials Handling,** sponsored by The Industrial Management Center, The Lake Placid Club, Essex County, New York.

June 19–23: **Recent Industrial Engineering Developments,** University of Michigan, Ann Arbor, Michigan.

June 19–23: **Automatic Optimizing and Computer Control Seminar,** sponsored by the Case Institute of Technology, University Circle, Cleveland 6, Ohio.

June 19–30: **Systems Engineering,** University of Michigan, Ann Arbor, Michigan.

June 19–30: **Human Engineering Concepts and Theory,** University of Michigan, Ann Arbor, Michigan.

June 19–30: **Value Engineering,** University of California, Los Angeles, California.

June 19–30: **Digital Control Systems Engineering Course,** sponsored by the Case Institute of Technology, University Circle, Cleveland 6, Ohio.

June 25–30: **Research and Development Management Development Seminar,** Pennsylvania State University, University Park, Pennsylvania.

June 26–30: **Annual Meeting of ASEE** at the University of Kentucky, Lexington, Kentucky .

July 10–14: **Technical Report Writing for Engineers and Scientists,** University of California, Los Angeles, California.

July 10–21: **Foundations and Tools for Operations Research and the Management Sciences,** University of Michigan, Ann Arbor, Michigan.

July 10–21: **Recent Mathematical Advances in Operations Research,** University of Michigan, Ann Arbor, Michigan.

July 10–21: **Modeling and Simulation in Operations Research,** University of Michigan, Ann Arbor, Michigan.

July 10–21: **Advanced Data Processing Techniques,** University of Michigan, Ann Arbor, Michigan.

July 10–28: **Process Control Theory Course,** sponsored by the Case Institute of Technology.

July 23–August 4: **The Tenth Annual Columbia Utility Management Workshop,** Columbia University, New York 27, New York.

August 21–31: **Quality Control by Statistical Methods,** University of Michigan, Ann Arbor, Michigan.

September 5–15: **Statistical Methods and Advanced Quality Control,** Purdue University, Lafayette, Indiana.

September 12–15: **Seminar for Manufacturing Engineers,** Pennsylvania State University, University Park, Pennsylvania.

September 17–22: **Work Measurement Conference,** Pennsylvania State University, University Park, Pennsylvania.

I.E. OPPORTUNITIES

The I.E. Opportunities service is a functional committee activity of the AIIE. Information concerning employment opportunities is collected on a nationwide basis and is provided without charge to members upon request. The committee is composed of members from the Metropolitan New York chapter.

SERVICES PROVIDED

Current job openings are published in condensed form in each issue. In addition, a monthly I. E. Opportunities Bulletin is supplied to over one hundred chapters located throughout the U.S.

Each job opening is assigned a **"P"** number for identification. The name and address of the person to contact for additional information concerning a specific job opening is sent to members on request.

EMPLOYERS

Employers having openings for qualified Industrial Engineers are invited to list them. Government agencies and educational institutions as well as business and industry are urged to take advantage of this free service.

To list your job openings with the Opportunities Service, send all or part of the following information with the name of your contact man to the address below: Type of industry, location, job classifications, minimum educational and experience qualifications, and salary range.

MEMBERS SEEKING JOB OPPORTUNITIES

The following list shows job openings available just prior to press time. If you would like more information about one or more of the positions listed, mail the **"P"** numbers with your name and address to the Opportunities Service at the address below. The Service will advise you by return mail of the name and address of the person to contact for further information, or advise you if the position is no longer available. Your name will not be forwarded to the company with the job opening.

For more current listings, contact your local Chapter Secretary or Opportunities Chairman for the latest monthly Bulletin.

ADDRESS OF THE SERVICE

I. E. Opportunities Service
American Institute of Industrial Engineers
32 West Fortieth Street
New York 18, New York

Position number	Industry, location		Travel?	Job classification number (See key)	Salary range $1,000	Qualifications required		
						Years of exp.	Age range	Remarks
41	Consulting	Ohio	×	10, 21, 31		5-7		
167	Weapons Systems	Wash. D.C.		50				Ph.D.
213	Air Force and Missiles	Calif.		12, 15, 32, 42, 43, 44, 53	5.3-7.5	0-3	21-	B.S. in I.E.
273	Air Force	Utah		11, 13, 18, 42, 43, 44, 53	6.3- 7.5	2-		I.E. Degree
423	Air Force	Ohio		Broad	8.8			I.E. Degree
424	Air Force	Ohio		Broad	4.5- 7.5			I.E. Degree
449	Electronics	Mass.		30, 50, 70	6.0- 8.0	1-5		
464	Consulting	N.J.	×	10, 20, 32-34, 42, 43, 54, 71-73, 92	8.0-12.0	5-	30-36	I.E. Degree
465	Consulting	Mass.	×	Senior Engineer	12.0-15.0	10-15	32-50	I.E. Degree or Equiv.
472	Plastic and Wood Prod.	Va.		11	8.0- 8.5	1-2	-30	MTM Experience(Woodwkg.)
493	Plumbing Supplies	Ohio		11, 13, 18	7.5- 9.0	7-	30-35	I.E. Degree
499	Electronic Equip.	N.Y.		10, 36	Open	3-		I.E. Degree or Equiv.
503	Electronics	D.C.		30	9.0-11.7	5-		I.E. Degree
514	Air Force	Ohio	25%	12, 17, 18	8.8-10.0	4+-		B.S.I.E. or M.S.I.E.
515	Air Force	Ohio	25%	40	8.8-10.0	4+-		B.S.I.E. or M.S.I.E.
516	Air Force	Ohio	25%	32, 37	8.8-10.0	4+-		B.S.I.E. or M.S.I.E.
517	Air Force	Ohio	25%	10, 13, 16	8.8-10.0	4+-		B.S.I.E. or M.S.I.E.
518	Air Force	Ohio	25%	Broad I.E.	8.8-10.0	4+-		B.S.I.E. or M.S.I.E.
519	Automotive Parts	Mich.		10, 11, 13, 19, 26, 36, 38, 42	6 0- 9.0	7-20	30-45	College Degree
534	Glass Containers	N.Y.	25%	10, 11, 22, 36, 43,	7.5-10.0	3-5	-40	I.E. or M.E. Degree
538	Papermaking	Pa.		50, 51, 52, 53, 54,55	Open	2-5	25-35	M.S.I.E.
539	U. S. Army	Ill.	×	37, 52, 53, 54	8.8- 9.5	3-		B.S. Degree
542	Electronics	N.Y.		19, 42, 43	5.2- 8.5	0-3		B.S.—I.E., I.M., or M.E.
543	Air Force (Maint.)	Pa.		11, 13, 18, 44, 53, 91	7.5	4-	25-40	I.E. Degree
545	Consulting	Pa.	×	10, 20, 30, 40, 50, 70, 90	8.0-10.0	5-	28-40	M.E. or I.E.
553	Sugar Refining	Md., La.		11, 36, 38, 43	6.2-9.0	0-5		I.E. Degree
556	Office Machy.	Mich.		30	9.6-	3-5		Exp. in Quality Contro
570	Transportation*			10, 30, 42, 43, 47	7.0- 8.4	4-	20-	I.E. Degree
571	Transportation*			10, 30, 42, 43, 47	6.0-	None	20-	I.E. Degree
572	Mgmt. Consultant	U.S.A. & Europe	×	10, 11, 13-18, 21, 22, 91 or 92	Open	5-	30-40	MTM Experience
585	Garment Mfg.	N.J.		10	5.2- 5.7	0-2		I.E. Degree
587	Naval Avionics	Ind.		11, 30, 40, 70	6.4- 7.5	2-5		I.E. Degree
588	Printing	Ohio		10, 20, 31, 42, 43	Open	2-5	-30	B.S.I.E. or M.S.I.E.
593	Metal Working	Mich.		10, 11, 13, 20, 39, 42	10.0-	10-		Engineering Degree
594	Chemical Mfg.	Tex.		Methods Analyses	8.0	2-6	-35	B.S.I.E. or B.S.M.E.
595	Plastics	Ill.		11, 42-46	7.2- 8.4	5-		B.S.M.E. or B.S.I.E.
601	Wood and Plastics	Va.		21	7.5- 8.0	2-3	25-35	B.S. Degree
603	Training	Mich.		30—in Metal Cutting	7.0-	3-5	25-	B.S., M.S., Ph.D. I.E., M.E.
604	Training	Mich.		30—in Plastics	7.0-	3-5	25-	Same as above
607	Elect. Controls	Mass.		30,32,39	10.0-12.0	5-10	-40	I.E. or M.E. Degree
609	Research & Devel.	Md.		30, 40, 42		8-		B.S.I.E.
610	Research & Devel.	Md.		30		5-		B.S.I.E.
611	Research & Devel.	Md.		30		3-		B.S.I.E.
615	Heat Trans. Equip. Mfg.	Wis.		11, 19, 32, 38	6.6-	3-	-45	B.S.I.E. Pref.
620	Food Machy. Mfg.	Iowa		36, 42, 43	6.0- 8.0	5-		M.E. Deg. or 2-3 Yrs. Col.
621	Boats	Mich.		30, 40	6.0- 8.4			
622	Casing Testers	Texas		30, 71		3-5	-35	B.S.I.E.
623	Semiconductors	Mass.		11, 13, 16, 18, 42	8.0-11.0	3-5		
624	Navy	D.C.		44, 49, 54, 70	4.5- 7.5		Open	
626	Mining, Milling, Smelting	Utah		13, 21, 26	7.0-10.6	3-8	25-35	Engineering Degree
630	Textile & Paper Prod.	Tenn.		10, 11, 13-15, 18, 21, 22, 26, 36	6.0- 7.5	2-3		I.E. Degree or Equiv.
631	Air Force (Maint.)	Pa.		10, 11, 13-15, 18, 30-34, 39-47, 90	7.5	3	20-	B.S.I.E.
632	Air Force (Maint.)	Pa.		10, 11, 13-16, 18, 30-34, 39-47	7.5	3	20-	B.S.I.E.
633	Air Force (Maint.)	Pa.		10, 11, 13-16, 18, 30-34, 39-47	6.2	2	20-	B.S.I.E.
634	Air Force (Maint.)	Pa.		10, 11, 13-16, 18, 30-34, 39-47	4.9	0	20-	B.S.I.E.
635	Air Force (Maint.)	Pa.		10, 11, 13-16, 18, 30-34, 39-47	5.8	1	20-	B.S.I.E.
636	Air Force (Maint.)	Pa.		10, 11, 13-16, 18, 30-34, 39-47	6.2	2	20-	B.S.I.E.
639	Education	N.Y.		10, 30, 40, 50, 60	9.0-12.0	5-15		Ph.D. in I.E.
640	Athletic Equip.	Ohio		11, 13, 16, 18, 19, 26, 32-34, 42, 44	8.4-	5-6	30-40	MTM required
641	Athletic Equip.	Ohio		11, 13, 16, 32, 42	6.5-	3-4	25-45	MTM required
643	Pharmaceutical	Ind.		10, 11, 13-15, 18, 19, 42, 43, 53	6.0- 6.5	0-3		I.E. or M.E.

*Openings in New York City, Detroit, Mich., Syracuse, N.Y., Indianapolis, Ind., and Cleveland, Ohio.

Position number	Industry, location		Travel?	Job classification number (See key)	Salary range $1,000	Qualifications required		Remarks
						Years of exp.	Age range	
645	Management Cons.	Minn.	40%	13, 31, 37, 43, 54, 55, 71, 72, 91	11.0–	5–	29–45	Engineering Degree
647	Printing	Eastern U.S.		30	Open		30–45	B.S. in I.E. or Equiv.
651	Propane Equip.	Ill.		10	5.4– 6.0	3–		Degree not required
653	Research Lab.	Md.		30, 40 (Principal Engineer)		3–		B.S.I.E.
654	Research Lab.	Md.		30, 43 (Methods Analyst)		3–		B.S.I.E. or I.M.
655	Film and Paper	N.C.		10, 20, 30, 42, 43, 49, 53, 70, 73, 81	Open	0–5	21–30	I.E. Degree
656	Forgings, Stampings, etc.	Northeast		(Division Manager)	15.0–18.0	8–10	35–	I.E. Degree
658	Food Proc.	Minn.	Ltd.	10, 20, 30, 40, 81	5.7– 6.1	0–2	Open	I.E. or I.M. Degree
660	Consulting	N.Y.	×	10, 21, 36, 38, 91, 92	12.0–20.0	8–	35–45	M.E. or I.E. Degree
672	Electronic	N.Y.		10, 30, 42, 43	–12.0	5–		M.S. or B.S. in I.E.
673	Electronic	N.Y.		11, 13, 36	–12.0	2–		Electronic Exp.
675	Power Farm Machinery	Iowa		General	Open	2–5	30–45	I.E. Degree
676	Clay Products	Tex.	Ltd	12, 21, 36, 42, 43	5.8– 6.6	5–	28–35	I.E. Degree or Equiv.
679	Education	Conn.		Asst./Associate Professor				Doctor's Degree in I.E.
680	Pulp & Paper	Maine, Pa.		11, 31, 37, 43, 49, 91	6.0–	Open		B.S.I.E.
686	Lamp Mfg.	N.J.		10, 11, 14, 15, 20–23, 90, 92, 95	9.0–12.0		35–	I.E. Degree
687	Wood Furniture	Mo.		10, 11, 13, 21, 22, 36, 39, 47	7.0– 9.0	5	30–40	I.E. or M.E. Degree
688	Metal	Ind.		10, 13, 15, 30, 36, 40	Open	8–10	30–35	B.S.in Ind. Engineering
689	Corrugated Containers	Midwest		10–16, 21, 26, 60	6.0– 8.0	2–5	25–35	I.E. or M.E. Degree
690	Optical	N.Y.		10, 13, 19, 20, 36, 38, 42	9.0–12.0		35–45	I.E., M.E., and E.E. Degree
691	Navy	Hawaii		10, 20, 30, 40, 60, 70	7.5–	4		I.E. or Equiv.
693	Education	Ohio		31, 37, 38, 50	Open		30–50	Master's Degree Pref.
695	Electronics	Calif.		30, 32, 38, 39, 44	7.2	3		
703	Tobacco Mfg.	W.Va.		11, 18, 42, 43	Open	1–3	23–28	I.E. Degree, must have satisf. Milit. Serv. Requirement
704	Government Agency	N.Y.		10–19, 70–72	6.4– 7.5	3–		B.S.I.E.
706	Tire & Rubber	Ohio		10–20, 36, 38, 70	8.0	3–4	–30	I.E. Degree
707	Education & Research	R.I.		10–20, 30, 40, 60	6.4– 7.5			I.E. Degree
708	Mining, Milling, Smelt.	Nev.		10, 11, 13, 14, 21	6.5–10.5	2–	–45	I.E. Degree or Equiv.
709	Textile	N.C./S.C.		28 for S.C. 10, 11, 18, 21, 26 (or N.C.)	7.0–	3–	–25	I.E. Degree
710	Food Processing	Minn.		50, 51, 52, 53	8.0–10.0	2–	25–35	M.S. in I.E. or Applied Math.
712	Motor Mfg.	Ark.		10–20, 30, 40	6.0– 7.0	0–		I.E. Degree
714	Navigation	Calif.		10, 36, 37, 38, 42, 43, 50, 53, 91	8.0–14.0	3–12	24–40	B.S.I.E., M.S.I.E. or Equiv.
715	Education	Mich.	Min.		7.0–	3–5		B.S., M.S., Ph.D. I.E. or M.E. with desire to teach
717	Chemical	Mass.		19, 20–33	7.0– 9.0		Open	I.E. with Mechanical, Aeronautical Eng. Background
718	Rubber	Md.		10, 11, 15, 19, 21, 26, 30	Open			I.E. Degree or Equiv.
720	Textile	Ga.		10–15, 18, 21, 22, 23, 34	6.0– 7.0	0–3	30–	I.E. Degree
721	Paper	Va.		10–18, 30–36, 41–47, 52, 53, 70, 81	6.4–	3–	–30	I.E. Degree
722	Forest Products	Ark.		11, 30, 48	Open	3–4		I.E. Degree and or Adv. Degree
723	Forest Products	Ark.		10, 11, 13	Open	3–4		I.E. Degree and or Adv. Degree
726	Bedding	Minn.		11, 18, 30, 32, 35, 36, 40, 92	15.0–19.0	5–10	35–40	I.E. Degree
727	Grain Milling	Iowa		10, 11	Open			Prefer Grain Milling Exp.
728	Textile	N.C., Va.		10, 11, 14, 22, 28, 91	6.0– 8.0	2–6	21–35	College Graduate
730	Sugar Refining	Pa.		10, 19, 36, 43	–6.6	0–1		Jr. I.E. Degree
731	Sugar Refining	Pa.		10, 19, 36, 43	–8.1	3		
732	Electronics	Md.		37—Section Chief		6–8		Design & Quality Control
733	Electronics	Md.		30—Section Chief		10		Experience in Prod. Tech.
735	Air Force	Pa.	Occ.	10, 11, 14, 15, 13, 16, 18, 30–34, 39–47	7.5	3	20–	B.S. in Engineering
736	Air Force	Pa.	Occ.	10, 11, 13, 14, 15, 16, 18, 30–34, 39–47	6.4	2	20–	B.S. in Engineering
737	Mfg. Heavy Ind. Equip.	Wis.		19, 30, 32, 34, 36, 44, 47, 53, 90	10.0–15.0	10–		Engineering Degree
739	Education	Conn.		Assist. or Assoc. Professor				Doctor's Degree in I.E.
740	Semiconductor	Fla.		70, 18, 12, 34, 50, 36	–7.5			B.S.M.E. or I.E. Pref. Rec. Graduate top ¼ Class.
741	Instrumentation	Texas		70, 80	7.2– 9.6	3–5	–35	B.S. in I.E. or M.E.
742	Chemical	N.M.		Mechanical Inspector	8.0	3	–35	B.S. in I.E.
743	Chemical	N.M.		Mining	9.6	5	–35	B.S. in I.E.
744	Chemical	N.M.		11	7.5	5	–40	B.S. in I.E.
745	Chemical	Southwest		Jr. I.E.	7.2	2	–35	B.S.I.E.
746	Food	Texas		11, 15	6.0– 7.2	2–	–35	B.S.
747	Chemical	Texas		11	8.0– 8.5	2–	–35	B.S.I.E. or M.E.
748	Food Processing	Minn.	Lim.	70, 71	6.0– 7.3	2–4	Open	I.E. or I.M.
750	Mfg. Athletic Equip.	Ohio	15%	11, 14, 21, 30, 32, 40, 47, 70	6.0– 9.0	2–10	25–35	B.S. Engineering
752	Steel Foundry	Pa.		10, 11, 13, 14, 15, 18, 21	6.0– 7.0	0–5		I.E. Degree
753	Printing	Ohio		31, 33, 35, 19	Open	2–	–35	
755	Electro. Mech. Mfg.	Ill.		11, 15, 22, 36, 38, 39, 40, 92	10.0–15.0	10–15		B.S.I.E. or M.E. 10 Yrs. Supervisory Exp.
756	Electronics	Md.		Technical Sale	15.0–20.0			Background in Sales or as Proj. Leader
760	Electronic Equip.	N.Y.		11, 13, 16, 18, 32, 34, 39, 42, 43, 63	6.5– 8.5	2–5 Pref. Elec.	21–40	I.E. Degree or Equiv.
761	Electronic Equip.	N.Y.		11, 15, 18, 38, 42, 53, 70	6.5– 8.5	2–5 Pref. Elec.	21–40	I.E. Degree or Equiv.
762	Electro-Mech.	N.Y.		Asst. to President	10.0–13.0 and Prof. Shar.	Pref. Mfg.		College Degree
764	Airline	Ill. Colo. Calif.	15%	11–13, 17, 42, 43, 49–52	6.0–10.0	1–5	–40	I.E. Degree of Equiv.
765	Plastics	Va.		Methods Engineer	– 8.1	2–5	28–45	I.E. Degree or Equiv.
766	Wood	Va.		10	– 7.8	4–6	30–45	I.E. Degree or Equiv.
767	Heavy Mach. Shipbuild.	Va.		10, 15, 18, 19, 21, 36	6.0– 8.5	0–5	21–35	I.E. Degree of Equiv.
768	Wood Plastics	Va.		10, 21	7.5– 8.5	2–5	25–35	College Degr. or Equiv.
769	Wood, Plastics	Va.		Junior Project Engineer	5.0– 5.5		–30	I.E. Degree or M.E.
770	Wire	Wis.		21, 26, 28	10.0	5–	30–35	Several Yrs. as Chief I.E. Pref.
772	Chem. Mfg.	Tex. La.		10, 11, 13, 14, 18, 36, 38	6.0– 9.6	0–5	21–26	B.S., M.S., I.E., M.E., or Equiv.
773	Education	Kan.		10, 20, 30, 40, 50, 60, 70, 80, 90 (not all)	7.5– 8.5			Teaching & Ind. Exp., Opport. for Con.
774	Pulp & Paper	Calif.		11, 30, 36, 41, 42, 43, 44, 45, 46, 47, 52, 53, 71, 81	Open	2+	Open	B.S., I.E., or M.E., M.S. or M.B.A. Pref.
775	Rubber Sundries	N.Y.		18, 13, 21, 36	7.2	1–3		I.E. Degree
776	Varied	Europe or S.A.	Reloc.	49, 54, 70, 71, 72, 73	Open	5–		
777	Varied	Europe or S.A.		11, 13, 21, 31, 37, 45	Open	5–		
778	Textile	Europe or S.A.		11, 13, 21, 31, 37, 45	Open	5–		
779	Knitting	Europe or S.A.		49, 54, 70, 71, 72, 73	Open	5–		
780	Mil-Elect.	Md.		Chief, Production Engineer	Open	10–		B.S.I.E. or M.E.
781	Oil	Middle East		10, 30, 40, 70	13.0–17.0	7	30–40	College Degree
782	Air Force	Ala.		12–19, 31–38, 49–54, 71, 93	12.21–13.51	5–6		B.S.I.E. or M.S.I.E.
783	Air Force	Ala.		11–19, 30, 47, 49–54, 71, 93	12.21–13.51	5–6		B.S.I.E. or M.S.I.E.
784	Air Force	Ala.		11–19, 30–38, 43–47, 49–54, 81, 92	10.635–11.935	4–5		B.S.I.E. or M.S.I.E.
785	Air Force	Ala.		12–19, 31–38, 49–57, 71, 92	10.635–11.935	4–5		B.S.I.E. or M.S.I.E.
786	Air Force	Ala.		11–19, 30–47, 49–54, 91	7.56–10.225	3–4		B.S.I.E. or M.S.I.E.

Position number	Industry, location		Travel?	Job classification number (See key)	Salary range $1,000	Qualifications required		
						Years of exp.	Age range	Remarks
790	Education	Ohio		10, 30, 50	Open		Pref. Rec. Gradu.	M.S. in I.E. or M.E. Strong in I.E.
791	Education	Fla.		11, 28, 30, 31, 42, 47, 70, 71	Open	4–	30–45	M.S. or Ph.D. in I.E.
792	Mgt. Consult.	U.S.A. & Europe	Yes.	11, 13, 15, 21, 22	Open	5-7	35–	MTM. Exper. Foreign Lang.
793	Mgt. Consult.	U.S.A.		11, 13, 15, 21, 22	Open	5-7	35–	MTM. Exper.
794	Education	Va.		30, 39, 42, 43, 44, 47	5.2- 7.0	3–		M.S.I.E. Min. Pref. Ph.d.
795	Elect.	N.J.		10, 30, 42, 36	6.5- 8.7	0-3		I.E. Degree
796	Chem.	N.J.		Jr. I.E.	6.0			I.E. Degree & Time Study Exp. Pref.
797	Chem.	N.J.	Some	92	15.0+	Heavy		I.E. Degree & Multi-Plant Paper Exp.
798	Chem.	N.J.		92	10.0+		Open	I.E. Degree & Heavy Time Study
799	Hospital	Ohio		11, 12	Open	1-5	No Limit	
800	Electronics	Md.		94	10.0-13.0	10–		B.S.I.E. or M.E.
801	Heavy Ind. Equip.	Wis.		40, 44, 48, 90	10.0-14.0	5-10		M.E.
802	Heavy Ind. Equip.	Wis.		48	8.4- 9.6	5-7		E.E.
803	Prec. Parts Mfg.	Ore.		Qual. Control Mgr.	-12.0	Ext.		Engineering Degree
804	Metal Fabric	Calif.		31 (Mgr.)	Open	3–		I.E. Degree
805	Electronics	Calif.		Various	Open	2–		I.E. Degree
806	Hospital	Pa.		11, 12, 70, Assist. to V.P. Admin.	10.0-12.0	Open		I.E. Training
807	Gov't Agency	Various		Research & Devel. Adm.	6.4-13.7	Vary		College Degree
808	Food	La.		11, 18, 36, 38, 40	Open	0-5		B.S.I.E.
809	Food	N.C.		92+Staff Level	Open	10–	35–	I.E. Degree
810		South Amer.		Asst. Chief Engineer	-12.0+			
811	Printing	N.Y.		11, 13, 36	8.5-11.5	Open		I.E. Degree
812	Meat Packing	N.Y.		13, 14, 33, 94	7.0- 8.0			I.E. Degree Exp.
813	Printing	N.Y.	25%	11, 13, 15, 16, 18, 34, 53	7.0-12.0	2–		B.S.I.E. or M.S.I.E.
814	Meat Packing	N.Y.		36, 14, 11, 42	Open	2-8		B.S.I.E. or Equiv.
815	Utility	D.C.		11, 13, 15, 18, 36, 37, 50, 91	9.0	3	25	B.S.I.E. or Adv. Degree
816	Research	Ohio		52 Project Research	7.8- 9.6			B.S.I.E. or Math. Phys. E.E.
817	Research	Ohio		52, Project Research	Open	3–		M.I.E. or Math. Phys. E.E.
818	Research	Ohio		System Analysis Consult.	Open	3–		Ph.D. in I.E. Math. or Stat.
819	Prec. Equip. Mfg.	Ohio	Some	Field Engineer	6.0- 7.2			B.I.E. or E.E. or M.E.
820	Glass	Ohio		31, 32	Open			Degree or Exp. in M.E.
821	Wood & Plastic	Va.		13, 14, 15, 21	8.0	3–	30–45	Deg. Desired
822	Wood & Plastic	Va.		37, 71	6.0- 8.0	3–	30–45	B.S.I.E. or M.E.Ch.E.
823	Wood & Plastic	Va.		Process Engineer	6.0- 8.0	2–	25–40	B.S.I.E. or Ch.E. or M.E.
824	Plastics	Va.		10, 11, 44, 45, 19	6.0- 8.0	2–	24–45	B.S.I.E., M.E. or Ch.E.
825	Wood	Va.		10, 11, 44, 45, 19	6.0- 8.0	2–	24–45	B.S.I.E., M.E. or Ch.E.
826	Mgt. Consulting	N.Y.	Yes	31, 35, 36, 41, 42	12.0-15.0	3+	30–35	B.S. Emphasis Prod. Control
827	Mgt. Consulting		Yes	10, 11, 12, 13, 16	-11.0	3+	28–38	B.S.
828	Metal Stamping	South		30, 95, 65, 48, 39	15.0–	10–15	35–45	B.S.I.E. or M.E.
829	Hvy. Machinery	East Cst. Q		92, 10, 20	16.0–	15	35–45	B.S.I.E.
830	Paper	Va.		10–19, 26, 30–38, 40–47	Open	0-5	Open	B.S.I.E. or M.E.
831	Gov't. Mfg.	Ga.		30, 32, 39	7.56-8.86	3(1 ME)		B.S. in Eng.
832	Gov't. Mfg.	Ga.		32, 39, 53, 90	8.955-10.255	3+1 ME		M.E. Degree
833	Airline	N.Y.	30%	12, 13, 50	9.0-12.6	-10		Eng. Degree
834	Fabric	N.Y.		11, 12, 13, 14, 17, 18, 22, 23, 32, 33, 34, 36, 42, 43, 53	Open	8–	Open	B.S.I.E. and Diversified Exp.
835	Petroleum	Fla.	–5%	54, 70	7.5-10.0	5–	-35	Deg. Spanish Helpful
836	Education	Calif.		30, 50, 52, 54	Open	3–	Open	B.S.I.E. (Minimum)
837	Paper	La.		11, 12, 13, 18, 31-35, 41, 42	7.0- 8.5	2-4	25-35	I.E. Degree
838	Synthetic Fibers	N.C.		I.E.	- 9.0	4-6	-40	B.S.I.E.
839	Mgt. Consulting	V.S.+For.	×	10, 11, 13-18, 21, 26, 91-93	Open	5-10	30-45	I.E. and/or Adv. Degree
840	Machinery	Pa.		11, 19, 91	6.5- 7.0	2–		
841	General Contractors	Texas	25%	18, 32, 33, 34, 50, 70	6.0- 8.4	2-5	-35	B.S.I.E.
842	Chemical	Pa.		42, 36, 32, 33, 38	Open	4-5		Eng. Degree
843	Pressed Steel			Quality Control Manager	12.0		30-40	I.E. or M.E.
845	Mgt. Consulting	N.Y., Ill.	Yes	16, 21	-12.0	3+	28-38	B.S. Degree

Key to Job Classifications

No.	Job Classification
10	Motion and Time Study
11	Methods Improvement (Production)
12	Methods Improvement (Office)
13	Work Measurement and Perf. Stds.
14	Stop Watch Time Study
15	Std. Time Data Dev. & Applic.
16	Predeter. Elemental Time Stds.
18	Work Sampling
19	Estimating and Costing
20	Wage Payment
21	Incentive Plans
22	For Production Workers
23	For Non-Prod. Workers
24	For Supervisory Personnel
26	Job Evaluation
28	Wage Administration
30	Production Engineering
31	Production Control
32	Process Planning and Routing
33	Scheduling and Loading
34	Flow Process Charting
35	Inventory Control
36	Cost Anal. & Reduction
37	Statistical Quality Control
38	Budgetary Control, Standard Costs
39	Tool and Gage Design and Control
40	Plant Engineering
41	Plant Location & Expansion
42	Plant Layout
43	Material Handling
44	Machinery & Equipment
45	Specif., Select. & Eval.
46	Replacement
47	Automation
48	Plant Maintenance
49	Cap. Budget. Facil. Plan
50	Operations Research
51	System & Simulation with "Models"
52	Mathematical Analysis
53	Engr. Economy Studies
54	Auto. Data Proc. with Computers
55	Market Research & Forecasting
60	Industrial Relations
61	Personnel Administration
62	Personnel Testing
63	Personnel Training
64	Industrial Psychology
65	Labor Relations
66	Safety Engineering
67	Suggestion Systems
70	Systems and Procedures
71	Admin. & Operating Procedures
72	Organization Charts and Manuals
73	Records Admin. & Form Control
80	Product Design
81	Packaging
90	Management and Supervision
91	Industrial Engineering Supr.
92	Chief I. E. or Equiv.
93	Plant Engineer
94	Production Supervisor
95	Plant Mgr., Fact. Mgr., Works Mgr.
96	General Manager

Experimental curves	*Reference curves*
$d = 10$ mm (without contact pin)	MTM: Mc WF: SD-motion (tol $16 \leqq d < 50$ mm) BMT: MCV
$d = 10$ mm (with contact pin) tolerance 9.8 mm	MTM: $Mc+P(1\ Sd)$ WF: SD-motion+surface assembly (tol. 9.8 mm) BMT: MCV+precision factor 12.7 mm
$d = 5$ mm (with contact pin) tolerance 4.8 mm	MTM: $Mc+P\ (2\ Sd)$ WF: SD-motion+surface assembly (tol. 4.8 mm) BMT: MCV+precision factor 6.3 mm
$d = 2$ mm (with contact pin) tolerance 1.8 mm	MTM: $Mc+P\ (2\ d)$ WF: SD-motion+surface assembly (tol. 1.8 mm) BMT: MCV+precision factor 1.6 mm

As with MTM, a greater stress on the dependence on distance can be noticed with the BMT curve (MCV). It is remarkable that with this kind of motion the time values of BMT as related to the distance are always similar to those brought out by our own experiments.

In the second group we also compared the results of our experimental motion to a target of 10 mm in diameter (with contact pin) with the time values of the corresponding MTM, WF, and BMT motions. The calculated time values for this target motion are considerably higher with MTM ($Mc + P\,1\,Sd$), whereas the time values of WF and BMT are somewhat below our data. Once again, MTM lays greater stress on the distance moved than we do, whereas the angles of climb of WF and BMT correspond to that of our curve.

In the third group our 5 mm curve (with contact pin) may be compared with three curves of similar tolerance relationship. As regards the MTM curve ($Mc + P\,2\,Sd$) the same phenomena may be noticed which we stated in context with the MTM curve of the second group. Here, again, the time values for all distances are considerably higher and the angle of climb considerably steeper than with our curve. The WF curve is very similar to ours, but from a distance of 30 cm the angle of climb is less steep. The BMT curve is almost identical with ours.

Finally, in the fourth group, the curves with a target tolerance of 1.8 mm are analyzed. Compared with our 2 mm curve (with contact pin) the difference in the climb of angle of the MTM ($Mc + P\,2\,Sd$) curve is only relatively small, whereas the MTM value is greater by an average of 5 mmin. For a target tolerance of 1.8 mm the WF curve lies about 3 to 4 mmin above our curve at distances of less than 30 cm, whereas starting from this distance the angle of climb becomes less steep. Once again the BMT curve shows a very similar course, it is, however, about 2 mmin above the value discovered in our experiments.

To sum up we may say that all curves derived from the MTM tables show a greater dependence on the distance moved, a fact which might be seen from the steeper angle of climb. In addition, these curves in almost all cases lead to higher time values. Especially with greater distances the angle of climb of the Work Factor curves becomes smaller and smaller. In comparison with our results, the time values for small precision requirements seem to be too low, whereas on the whole the time values for high precision requirements seem to be too high. Almost all curves derived from the BMT system show the same angle of climb. The corresponding time values for the lowest and highest precision requirements are greater than those found out by us, whereas there is no substantial difference in the medium range of precision. Thus we may say that the time values for motions to a target vary considerably within the individual elemental time systems and that the values of none of the three systems consistently correspond with the results of our experiments.

EFFECT OF THE PRECISION OF A TARGET MOTION ON THE FOLLOWING MOTION

It is well known, as well as substantiated by the previous investigation, that the size of the target causes a deceleration of the previous motion. For example, when a plug is to be inserted into a hole, the time for the transport of the plug to the hole increases as the diameter of the hole and the difference between the diameters of the plug and the hole decrease. This fact has been taken into account by most elemental time systems. Since a precise motion is marked by a gradually increasing control of the motion up to the moment of touching or assembly, it may be assumed that this control cannot be reduced immediately. This means that there is an aftereffect on the motion following the assembly. This problem will be solved by the following series of experiments.

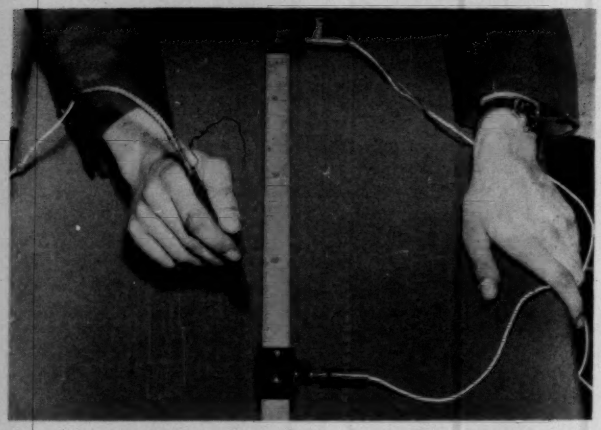


FIGURE 19. Investigation of the Effect of the Precision of a Target Motion on the Following Motion. (In this Figure the Distance Moved Amounts to 40 cm; whereas Our Experiments Were Carried through at a Distance of 36 cm.)

EXPERIMENTAL ARRANGEMENT

Figure 19 shows the experimental arrangement. Two targets of 3 mm and 30 mm in diameter lying side by side are opposite a single target of 30 mm in diameter at a distance of 36 cm. The subjects experimented upon are asked to touch in turn either of the two targets lying side by side with a contact pin, and to start these motions from the single target. Every time the contact pin touches one of the three targets a circuit is closed, so that it becomes possible to record the motion times by a vibrator oscillograph. By means of this recording it is possible to compare the time required for the way back from the 30 mm target and from the 3 mm target.

RESULT

On the whole the results of 7 persons with about 200 single motions each were analyzed. Table 1 shows the average time values of each person for the motion to the 3 mm target and for the ways back from the two targets as well as the corresponding mean deviations. The last column shows the differences between the two ways back, and here it becomes apparent that the way back from the 3 mm target takes about an average of 1.6 milliminutes = 22% longer with all subjects than the way back from the 30 mm target.

Thus, it is proved that the precision required to touch a target produces a decelerating effect on the following motion, This effect is of a magnitude that cannot simply be neglected.

Moreover, Table 1 shows clearly that, as the time for moving to the 3 mm target increases, the time for the way back increases as well. This may be considered as a confirmation of the result, since the time for the way back from the 30 mm target does not increase in the same degree.

The result of this series of experiments leads to the conclusion that is is necessary to integrate an additional factor into the elemental time tables which compensates for this increase in time.

INVESTIGATION OF TIME FACTORS DURING THE PERFORMANCE OF A SIMPLE ASSEMBLY

In the series of experiments described so far, we considered more or less isolated basic motion elements as to the physiologically optimum time for the distance moved and as to the different precision requirements. We shall now describe an experiment the arrangement of which is adapted in a higher degree to the practical working conditions in industry. The object of this experiment was to find an answer to the question as to whether the facts discovered in the previous experiments may be reproduced under more complex working conditions, i.e. to find an answer to the question as to what extent the results discovered so far may be generalized.

EXPERIMENTAL ARRANGEMENT

In this series of experiments a simple assembly work was performed. The task consisted in successively taking from a magazine 10 brass plugs of 3 mm in diameter and 50 mm in length, moving them along a variable distance, and inserting them each into one hole of a depth of 9 mm (see Figure 20). In the experiment the distances varied from 5 cm to 60 cm at intervals of 5 cm each. Furthermore the different plug-target tolerances were examined. In the first part of the experiments the internal diameter of the borings amounted to 3.1 mm, and in the second and third part it was increased to 3.4 and 4.6 mm respectively, thus increasing the tolerance from 0.1 to 0.4 and further to 1.6 mm.

Once again, after extensive preliminary experiments, this series was carried through with fifteen male persons of between 21 and 26 years. As to the different tolerances in the parts 1, 2 and 3 of the experiment and as to the grades 1 to 12 of the distance moved (5 to 50 cm) the sequences of experiments were strictly based on random figures, in order to obtain statistically acceptable results.

As to the measuring technique, the activity during the experiment could be broken down into four clearly distinctive elements:

TABLE 1

Effect of the Precision Required to Touch the Target on the Following Motion

Name of person	Way out to the 30 mm ϕ target (mmin)	Way back from the 3 mm ϕ target (mmin)	Way back from the 30 mm ϕ target (mmin)	Difference of the ways back (mmin)
Te.	11.18	7.83	6.30	1.5
Ku.	11.50	7.58	6.84	1.3
Ba.	11.70	7.87	6.83	1.0
Fe.	12.56	9.50	8.54	1.2
Gö.	13.72	8.50	6.45	2.0
Fo.	14.55	9.34	7.83	1.5
Ge.	15.30	11.50	8.99	2.5
Arithmetic mean		8.87	7.37	1.6

a. Grasp plug and take it out of the magazine.
b. Move plug to the boring.
c. Insert plug into the boring.
d. Backward movement of the arm to the next plug in the magazine.

The beginning and the end of these elements were defined as follows:

1. Beginning: first contact between finger and plug.
   End: breaking of the contact between plug and magazine.
2. Beginning: end of element a.
   End: first contact of plug with boring.
3. Beginning: end of element b.
   End: breaking of the contact between finger and plug.
4. Beginning: end of element c.
   End: beginning of element a.

These time values were recorded by an oscillograph with two channels. Since the paper feeding took place at a constant rate of 10 cm/sec., an accuracy of reading of $\pm$ 0.005 sec. could be obtained when analyzing the results.

On the whole, 36 different distances were selected for the experiments. Each subject had to overcome each distance on an average of 15 times during exactly 5 minutes each. Any of the 36 different distances with the respective motions repeated 15 times per distance had to be overcome twice. In one case the magazine was standing next to the person while the borings were lying at the far end, and in the other case the arrangement of the objects was reversed. One time a motion to a target had to be performed away from the body and another time it had to be performed toward the body. The amount of data obtained during these experiments was great enough that it is possible to make general statements on the relationship between elemental times and the total time for the assembly.

FIGURE 20. Experimental Arrangement for Investigating the Elemental Times with Assembly Work. (In this Figure the Plug-Target Tolerance Amounts to 1.6 mm.)

RESULT

With respect to the time required to perform motions with different precision requirements, within the range of 0.1 to 1.6 mm of the plug-target tolerance no significant difference in the time required to perform the motion elements "move plug to the boring" and "backward movement of the arm" could be noticed over the same distance. It has to be concluded from these data that with the exception of the following qualification it is of no importance to the average time required to perform these two motion elements, whether the tolerance amounts to 0.1 or to 1.6 mm. This applies to motions being directed away from the body, as well as to motions toward the body. At distances of between 35 and 60 cm only, there is a significant difference between the average time for these two motion elements with a plug-target tolerance of 0.1 mm. Apparently, the increasing difficulty of finding the target with a low tolerance and over a long distance produces a decelerating effect on the motion element "move plug to the boring."

The same relationship noticed in the series of experiments "effect of the precision of a target motion on the following motion" was found for the element "grasp plug and take it out of the magazine." In that series we discovered that a precise movement causes the slower performance of the following motion. The data for the element "grasp plug . . . " of this series reveal the remarkable fact that increasing precision requirements also affect the time required to perform the preceding motion element. We discovered the following facts:

Average gripping time with a target tolerance of 0.1 mm.: 1.85 mmin.

Average gripping time with a target tolerance of 0.4 mm.: 1.5 mmin.

Average gripping time with a target tolerance of 1.6 mm.: 1.2 mmin.

These differences are significant at a 5% level. Although these negligible differences are of no significance concerning the practical use of work studies, they nevertheless show that a complex motion is some sort of

"Gestalt," and that every element is connected with all the other elements in a way that all variations of an element (in this context it is the changing difficulty of the element "insert plug into the boring") may have repercussions on the following and the preceding elements. In this case the third element had repercussions on the first element of the cycle. A significant objection against the theoretical basis of predetermined elemental time systems as a whole goes back to this observation, and, to be sure, it was not by chance that Gilbreth, whose lifework was dedicated to motion study, did not realize his idea of elemental times being valid "once for all." His intensive study of the human motor action might have taught him what difficulties arise when trying to determine generally applicable elemental times. The authors of the elemental time systems here discussed were or are first and foremost excellent practitioners. Nevertheless, they ignored fundamental objections or were not aware of them. Thus, those persons applying these systems have to accept the fact that the microstructure of these systems shows considerable shortcomings.

When we continue analyzing the results of the assembly experiments, we find out that even from the average time values for the element "insert plug into the boring" some interesting knowledge may be derived. First of all, it has to be stressed that here, too, there is no significant difference between the times required to insert the plugs into the borings in either direction. At greater distances we expected clear differences with these experiments, since subjectively it seems to be more difficult to insert plugs into borings at a distance of for example 50 or 60 cm than to take them out of a magazine at that distance and to insert them into the borings right in front of the body. However, we could not prove this assumption experimentally.

When considering the relationship between the average time for the element "insert plug into the boring" and the plug-target tolerance, a real dependence may be pointed out. As to our three tolerances, there is a mean time ratio for all distances investigated of 1:0.86:0.68 for the tolerances of 0.1:0.4:1.6 mm.

We shall now turn to the question of the dependence of the individual elements on the distance moved. As to the element: "grasp plug and take it out of the magazine," no relation between the average elemental time and the distance moved could be proved. These findings confirm the results published by Vössius (25) in another context and correspond with the tables of various elemental time systems. As was expected, a true dependence on the distance moved exists with the time values of the elements "move plug to the boring" and "backward movement of the arm." At a distance of 5 cm the differences of the two elements as related to the plug-target tolerance are within the deviation limits of the experiment. As the distance of the target increases, the time required to perform the element "move plug to the boring" with very small tolerances increases more rapidly than the time for the element "backward movement of the arm." With regard to the element "backward movement of the arm" only a dependence on the distance moved, but no dependence on the tolerance could be noticed. On the way out from the body, and at a tolerance of 0.1 mm and a distance of between 35 and 60 cm, distance, tolerance, and time are correlated to each other, whereas with the other tolerances examined such an interrelation exists only between the distance moved and the time required for the way back.

It is not surprising that with the element "insert plug into the boring," time and tolerance are correlated to each other. The results of our experiments, however, show clearly, that there is also a correlation between time, tolerance, and distance moved. Between the distances of 5 and 60 cm, the time required to insert the plug increases within the three grades of tolerance as follows:

tolerance	*percent increase in elemental time*
0.1 mm	40
0.4 mm	31
1.6 mm	31

These facts coincide with the results shown in the section "Way-Time Relation of Free Target Motions as Dependent on the Size of the Target." This means, however, that—as was already stressed—the time values given in the tables of MTM and WF cannot lead to adequate total times of the motions requiring a high degree of precision.

Figures 21 to 23 show the elemental times recorded during our assembly experiments. We do not show a graph of the results of movements away from the body, since they do not differ substantially from those toward the body. The results are compared with the time values calculated for the same operation on the basis of various elemental time systems. In order to make them clearer the results are shown by curves. The time values developed by means of the MTM system are shown by summation curves in Figure 24. The total time for our assembly work was calculated on the basis of the following factors:

MTM:
1. Pick up grasp
2. Move
3. Position (*P*-2-*S*-difficult) for tolerances smaller than/equal to 0.8 mm
4. Release (*RL* 1)
5. Reach (R_A) to the next plug

As to their definition the following factors correspond to our elements quoted earlier:

$$a = 1, \qquad b = 2, \qquad c = 3 + 4, \qquad d = 5$$

Of the tolerances selected by us, only those of 0.1 and 0.4 mm are covered by the group *P*-2-*S*-*d*. Thus, the series

of experiments carried through with a tolerance of 1.6 mm is left aside. The summation curves for the total time of our assembly shown in Figure 21 are entered in Figure 24. The comparison of the total time discovered during our experiments and the synthetic total time calculated by means of the MTM system reveals some surprising facts. The total time recorded during our experiments is throughout considerably lower than the time calculated from its elements by means of MTM. We do not want, however, to define our attitude at this point, but we prefer to carry on our comparison with the other systems.

In Figure 25 the elemental times as calculated by means of the Work Factor system are again shown by summation curves. According to Work Factor the analysis of the motions performed during the experiment is based on the following elements:

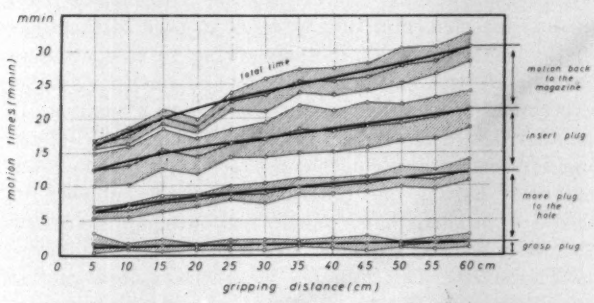


FIGURE 21. Elemental Times for the Assembly of a Plug. (Motions Are Directed toward the Body—Tolerance 0.1 mm.)

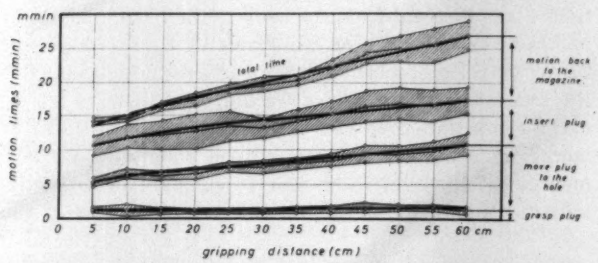


FIGURE 22. Elemental Times for the Assembly of a Plug. (Motions Are Directed toward the Body—Tolerance 0.4 mm.)

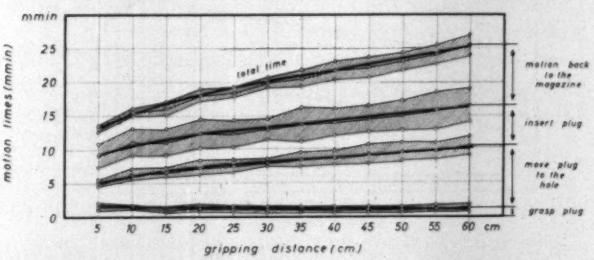


FIGURE 23. Elemental Times for the Assembly of a Plug. (Motions Are Directed toward the Body—Tolerance 1.6 mm.)

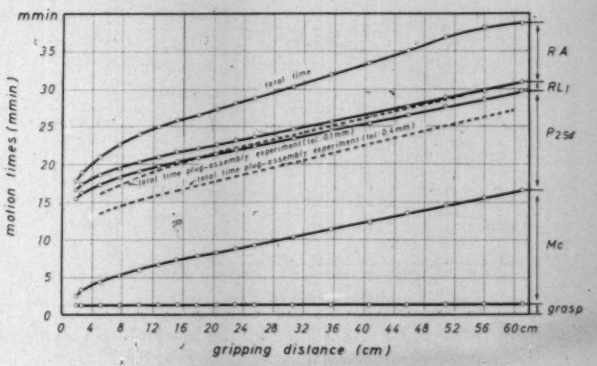


FIGURE 24. Setup of the Assembly. (Total Time as Calculated from Elemental Times according to MTM.)

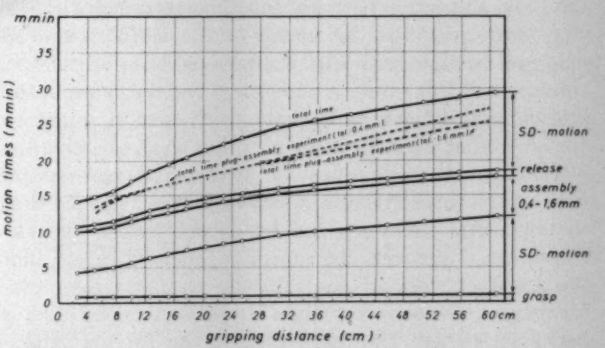


FIGURE 25. Setup of the Total Time for the Assembly as Calculated from the Elemental Times according to WF.

WF: 1. Grasp
2. *SD*-motion (way out)
3. Assembly at a tolerance of 0.4 to 1.6 mm
4. Release
5. *SD*-motion (way back)

Figure 25 shows the summation curves for the total time of our experimental assembly from Figure 22 and 23. As with MTM, we noticed in the Work Factor system that the times recorded during our experiments are considerably below the total time calculated on the basis of this elemental time system. In the case of Work Factor, too, for the sake of brevity we do not show the results of the experiments with a target tolerance of 0.1 mm on the graph.

In order to give a complete picture, the elemental times as calculated by means of the BMT system are shown as summation curves in Figure 26. The BMT curves are based on the following time elements:

BMT: 1. Grasp and move (*MCV*)—way out
2. Assembly (precision factor 0.8 mm)
3. Move (*RCV* + precision factor 1.27 cm)—way back

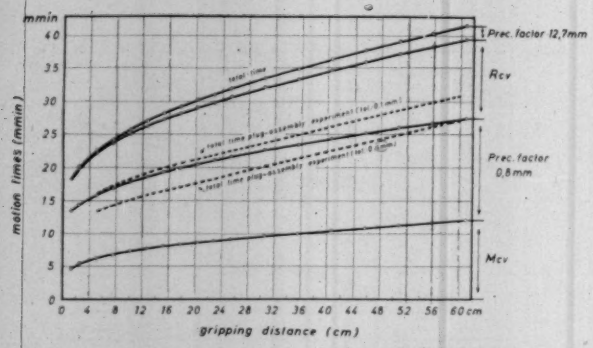


FIGURE 26. Setup of the Total Time for the Assembly as Calculated from Elemental Times according to BMT.

Once again, we entered into Figure 26 the summation curves for our total times from Figures 21 and 22, but we left aside the experiments with the tolerance of 1.6 mm. The difference between the time recorded and the total time calculated by means of the BMT system is even greater than with the two systems described above.

In view of this result, a question about the cause of the considerable differences is obvious. At first, it might be presumed that we made some mistakes when selecting the individual elemental times. On studying the procedural rules of the three systems, however, it will be found that the elemental times selected by us are proper for consideration. Moreover, the objection may be raised that the speed of work of our subjects, and thus their performance rates were very high. However, this objection is not valid either. The instructions given for the experimental work clearly said that a speed of work was to be chosen which could be maintained without interruption for several hours. There was no incentive. Moreover, no indirect influence may be imputed to the author, since the experiments were performed by an assistant. In addition, the experimental subjects were men not connected with the Max-Planck-Institute. We do not think it possible that the reference performance of our data is higher than that of the elemental time systems, if we may rely to some extent on the time values of 20 to 30% above normal performance mentioned previously.

Apparently with this series of experiments we seized on problematic points of the elemental time systems. As to the method, our experiments were planned in a way that the subjects performed one cycle after the other over a period of 5 minutes. After this time there was a short break which was followed by the next period of 5 minutes. The whole experiment lasted for two hours. Three to five experiments were carried through per week. The subjects showed a high level of skill. Experimental and practical experiences leave no doubt that a motion pattern is performed more smoothly and harmoniously the more frequently it is repeated. Also with optimum training, very exact motions to a target whose elements are repeated in the same way—even if the degree of tolerance and the distance moved are changed several times within an experiment—will be performed almost automatically, a fact that, as we very well know from other investigations, does produce an effect on motion time. In case the combination of motion elements is not repeated each time after 1.5 to 2 seconds, but perhaps only after some minutes' different work, no similar degree of automatic performance can be expected. Although even in the latter case the worker may be fully trained, as is required by the definition of normal performance, it still has to be expected on the basis of a different total structure of the work and with a high or low degree of subdivision of the production operations that the elemental times of work being broken down to a high degree become shorter than those of work in which the individual has to perform a greater number of elements. It is not necessary to discuss here the other disadvantages of work being broken down to a high degree.

When we first analyzed the results of our experiments, we presumed that the considerable differences over against the elemental time systems go back to the automatic performance of motions owing to a continuous training. It was easily possible to find out in a further experiment to what extent this assumption is justified. In another, less extensive series of experiments, the following experimental arrangement was set up for the same subjects: During one minute each of the subjects, by means of a small hand punch, had to punch holes into tickets in a fixed sequence (see experimental equipment of Figure 29). This minute's work was followed by an assembly cycle. The duration of the experiment was equal to that of the main experiment. These additional experiments were carried through only at distances of 5 cm, 30 cm, and 60 cm and at a tolerance of 0.1 mm, the motions being directed from the back to the front. The mean values of this experiment are shown by curves on Figure 27, in which interpolations were carried through between the measuring points. Since we did not intend to set up exact elemental, time curves for this combined form of work, we confined ourselves to the conditions already mentioned. In order to be able to compare these results with the main experiment, we entered into Figure 27 the

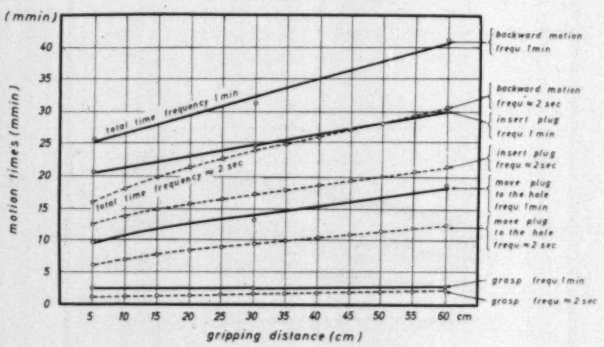


FIGURE 27. Effect of the Repetition Frequency on the Elemental Times of Plug Assembly. (Motions Being Directed toward the Body—Tolerance 0.1 mm.)

curves from Figure 21. There is a considerable difference between the undotted and the dotted curves, which proves impressively that the factor "repetition frequency of elements within the time unit" may by no means be neglected, if nearly adequate time values are to be derived from the elemental time tables. On the basis of this run it may be considered as proved by experiment that the total times of an operation developed synthetically may be too long, if this operation is continuously repeated. On the other hand, they may be too short, if the operation occurs relatively seldom, even though in the latter case the worker's general level of training—as related to the greater complex of activities—may be called satisfactory.

Repetition frequency of the work elements, however, is not taken into account in any of the systems known to us. Obections against such systems on the basis of this fact are especially serious, since the mistakes resulting from it in one or the other direction are to an extent that by far exceeds an acceptable degree.

CONSTANCY OF ELEMENTAL TIMES

It is one of the fundamental preconditions of any elemental time system that it is possible to break down any operation into a number of motion elements, each of which is of constant duration so that each element may be considered as an independent unit. On this assumption, which up to now has not been proved definitively by any system, it is said to be possible to combine these elements at will with other motion patterns, and to add and subtract their time values like mathematical quantities. This atomistic concept of the motion pattern, however, is seriously criticized by some scientists, such as Tolman (23) and Ghiselli and Brown (6). Ghiselli and Brown describe the following small experiment. The subjects were asked in a first series of experiments to press down a number of keys in the sequence A-B-C-D-E-F as quickly as possible (Figure 28). After a training period of sufficient length the motion time from one key to another was recorded electrically. In a second series of experiments, the motion C-D-C was dropped. The total time for this experiment was not equal, however, to the total time of the first series minus the amount of time required for the motion C-D-C, but in one case was greater by 5.8% and in another smaller by 12.7%. On the basis of these findings it is assumed that any work has to be considered as a whole with laws of its own and not as a sum of individual elements.

In the following series of experiments which involves rather frequent industrial activities, this problem is dealt with once again.

EXPERIMENTAL ARRANGEMENT

A small hand punch, a hand press for impressing eyes, and a magazine for the pieces not yet worked upon are arranged on the work place. A container for the finished

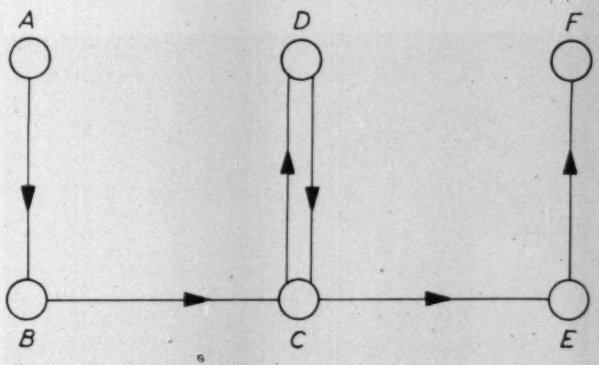


FIGURE 28. Experimental Arrangement as Setup by Ghiselli and Brown.

products is standing between the magazine and the punch, while the container for the eyes is placed between the punch and the press (Figure 29). The subjects are asked to punch two holes into tickets and to impress one eye into each hole. The operations were performed in the following sequence:

1. Take ticket out of the magazine.
2. Punch first hole.
3. Insert first eye.
4. Impress first eye into the ticket.
5. Punch second hole.
6. Insert second eye.
7. Impress second eye into the ticket.
8. Put ticket aside.

The fixture for impressing the eyes is connected with an electrical counter that records the number of pieces per minute. Working time amounts to three times 50 minutes per day, i.e. from 8 to 11 a.m. or from 9 to 12 a.m. respectively. After the subject has reached a performance level which can hardly be expected to be improved, the time values for the period from the impressing of the first eye to the impressing of the second eye are recorded during two days by means of an electronic chronometer.

Next the subject is asked to punch only one hole into the ticket, maintaining the same method, so that the following procedure will result:

1. Take ticket out of the magazine.
2. Punch first hole.
3. Insert first eye.
4. Impress first eye into the ticket.
5. Put ticket aside.

Once again, the number of pieces per minute is recorded and the work is continued, until no considerable improvement of the performance can be expected.

In each case, the reduction of the work to be done causes a shortening of the time per piece. When comparing the times per piece during the two operations, the question may be asked whether this reduction is equal to the time required to perform the subtracted work elements (from the impressing of the first eye to the impressing of the second one). In order to eliminate the

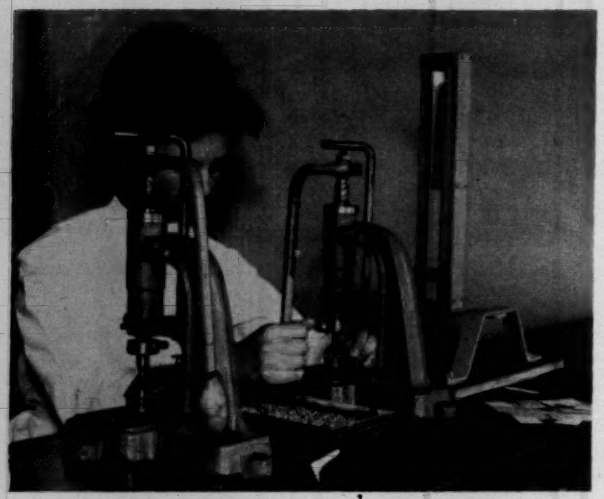


FIGURE 29. Experimental Arrangement for Impressing Eyes into Tickets.

effect of an improvement of the performance from the first series (two eyes) to the second one (one eye), the performance of a second group, starting with one eye and impressing two eyes in the following series, was measured at the same time. The mean value of the times per piece obtained by the two groups was calculated. The subjects were asked to maintain the method followed in the first series in the second series as well.

The subjects were twelve male clerks of 20 to 22 years divided into two groups (L and W). They were working on incentive.

RESULT

Figure 30 shows the development of the times per piece recorded for the two groups. The individual points are mean values of an experiment lasting for 50 minutes. The time valued used for the analysis, together with its standard deviation, is shown at the end of the respective curve.

	2 eyes (*min. per piece*)	*1 eye* (*min. per piece*)
Group L	0.110 ± 0.009	0.059 ± 0.006
Group W	0.120 ± 0.011	0.078 ± 0.004
Arithmetic mean	0.115 ± 0.011	0.069 ± 0.006

The work element from impressing the first eye to impressing the second eye subtracted from the time for impressing two eyes shows the following time value:

Group L	0.048 ± 0.009
Group W	0.055 ± 0.012
Arithmetic mean	0.052 ± 0.012

When subtracting this time value from the time per two eyes, the calculated value for impressing one eye amounts to 0.115 minus 0.052 = 0.063 min. Actually, however, this operation takes 0.069 min., i.e. about 10% more than was to be expected by the mathematical calculation. With a probability of $P < 0.1\%$ this difference of 6 mmin is very significant.

The result of this experiment suggests that the individual elements of an operation may not be considered as independent units of constant duration. When adding and substracting elements, we have at least to reckon on deviations from the calculated elemental times. Presumably, these deviations go back to the fact that men consider each work to be a whole, and build up the motion pattern in accordance with special rhythmic or other laws. We presume that one of these laws perhaps consists of the fact that an increase in the time for the work cycle leads to a shortening of all elemental times and that, vice versa, a shortening of the cycle leads to an increase in the remaining elemental times. Thus, it might be possible that the elemental times depend on the length of the work cycle. It has to be pointed out here that the assumed reduction of the elemental times of a cycle may not be confounded with a short-term improvement in the performance of repetitive elements within one cycle. There is, no doubt, an improvement of performance which will have to be considered in the elemental time system, as is shown in detail in a previous section; however, its effect will increasingly be noticed from the second to the last repetition, whereas the reduction in time presumed in this context becomes apparent almost steadily from the first to the last element and, to a certain extent, is provided by men in the plan of performance.

In the experiment described here, the time value of a

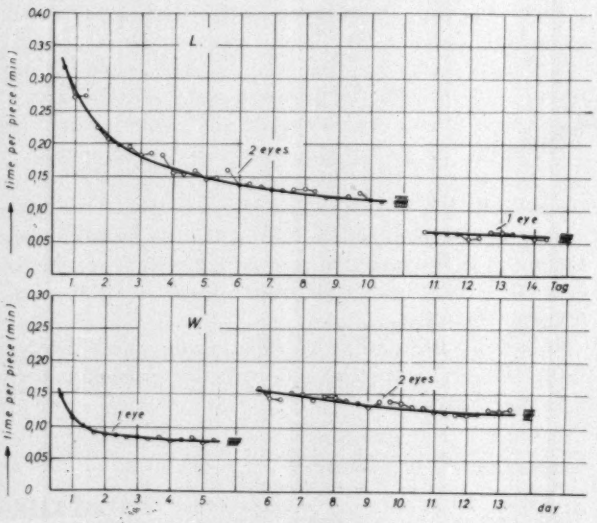


FIGURE 30. Time per Piece for Impressing One or Two Eyes into the Tickets.

group of elements was determined and it was found out that this time value deviated by 10% from the theoretically calculated value. When it is assumed that the motion elements of this group show a different reaction during the experiment, i.e. that the deviation of the sum represents a certain mean value of the deviation of the individual elements, this means that the deviations of the individual elemental times may show a greater percent value.

According to experiments carried through by Abruzzi (1), the interdependence and thus the variability of the elements is the greater, the smaller are the elements. Thus, it would be expedient, if possible, not to enter elements but groups of such elements into tables, since their time values are more constant. On the other hand, however, the fact has to be considered that the tables become gradually more extensive or less flexible the greater are the groups of elements. Thus, for the practical use of elemental time systems it is necessary, to make a compromise between these two concepts, and to find an optimum size of these groups of elements.

DISCUSSION OF THE RESULTS

After having pointed out the theoretical objections against the methodical foundations of predetermined elemental time systems, we are now able, on the basis of our seven series of experiments, to criticize these systems more specifically. However, it will have to be pointed out once again that our criticism is not directed against these systems as a whole, but that our objections are of a fundamental nature only, inasmuch as standard times for incentive work are developed by means of these systems. The advantages of these systems for the whole of methods engineering are almost completely disregarded in our criticism, since on principle no perfection of the determination of time values is aimed at in this context.

SPECIAL CRITICISM OF ELEMENTAL TIME SYSTEMS ON THE BASIS OF EXPERIMENTAL RESULTS

As a special advantage of their systems, the advocates of predetermined elemental time systems emphasize the fact that valid basic times may be developed without resorting to the problematical performance rating. This optimism, however, is by no means justified. Because of the uncertainty as to the performance of these systems, various European large-scale enterprises carried through comparative investigations, in the course of which times were developed by means of a predetermined elemental time system as well as by means of the traditional time study methods. In these investigations it was found out that comparative time values are developed only if the synthetic time values are multiplied by a constant factor (e.g. 1.2). However, since this corrective factor possibly involves a different concept of normal performance and of the performance rate, the basic time developed by means of these elemental time systems is by no means free from any subjective effect of performance rating.

In case this corrective factor is not correct, the error is increased to an extent that cannot be assumed in the traditional methods of developing standard times.

One of the elemental times occurring most frequently when developing standard times is the element for the arm motion ("move", "reach", etc.). The time values for this motion element are quoted for distances moved. In none of these systems is the direction of the motoin taken into consideration. We were able, however, to prove a dependence of the energy and the time required for a motion on the distance and the direction. Figure 9 shows that the time for a motion at an angle of about 145° with the front plane of the body and over a distance of 40 cm is about 20% greater than at an angle of about 55°. A similar observation could be made when comparing horizontal and vertical motions. Here, vertical motions were performed about 10% more quickly than the respective horizontal motions. These considerable differences in time required for a kind of motion which is possibly repeated several thousand times per shift may not be disregarded in the elemental time systems if approximately correct standard times are to be developed.

A further critical objection against the predetermined elemental time systems arises when considering the allowances provided for the same arm motions performed while the arm is carrying a weight (e.g. transport of a work piece). It is striking how few grades there are within the weight classes, the lowest of which ranges from 0 to 1.5 kg in the MTM, and from 0 to 0.9 kg in the Work Factor system. Our results showed a difference of about 60% in motion time for comparable arm motions without weight and with a weight of 1.5 kg respectively. This difference is so great that it may by no means be neglected. From these facts it is clear that the tables for arm motions with weights should be differentiated to a much higher degree.

An extremely important objection against the elemental time systems, which at the same time shows the wholeness of a complex motion pattern, results from the series of experiments described in a previous section. From these it is shown that the times required to perform a sequence of motion elements are directly dependent on each other. The time for the backward motion from a target of 30 mm and 3 mm in diameter is dependent on the size of the target to an extent that after having touched a target of 3 mm the backward motion takes an average of 22% longer than the way back from the target of 30 mm in diameter. This interdependence of preceding and subsequent motion elements has not up to now been taken into consideration in any of the predetermined elemental time systems, and with the great variety of possible motion combinations it is doubtful whether this interdependence can be considered in the time tables.

The systems discussed in this work also neglect the

effect of the repetition frequency on motion time. We asked the same highly skilled persons to do an assembly work at a frequency of about 2 seconds and then later to do it at a frequency of about 1 minute. During the series of assembly work interrupted by different activities and carried through at a frequency of 1 minute, the increase in time amounted to between 35 and 62%. We assume that these percentages grow as the duration of the intermediate work increases. Apparently, these observations were not made during the development of those systems, since we do not suppose that the authors of the various elemental time publications would neglect such time deviations. If the repetition frequency of the motion elements is not taken into consideration, an error of unknown extent enters the final time values.

Finally, in our last series we proved that the elemental times are not constant. When omitting one element from an operation, the time per operation is not reduced by the elemental time value of this omitted element, but the remaining elemental times increase by an average of about 10%. From this it may be concluded that elemental times are not mathematical quantities which may be added or subtracted without hesitation. Thus, we proved experimentally what we found in the general criticism of elemental time systems as a consequence of the investigations carried through by Klemm and his staff, and Derwort: The sum of the times required to perform motion elements is not identical with the whole motion pattern. The confronting of the principles of predetermined elemental time systems with this experimentally substantiated thesis means the denial of the general validity of elemental times. But valid time values are a precondition of just standard times. If the validity of elemental times has to be denied for complex operations, we have no basis for deriving work standards from elemental times. We do not mean to say that these systems have no place among the methods of work technology. They may be of great value to the planning of work and to methods engineering. Performance rating and thus wage payment, however, ought to be based on systems whose possible dispersion of errors remains within certain limits.

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Performance Review—A Method of Controlling Indirect Effort

by **WALTER L. BALK**

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FOR MANY years management and Industrial Engineers have been trying to develop satisfactory methods of work measurement for all types of jobs. An ideal solution would be to define and control each individual position, whether it is that of a punch press operator, machine accounting technician, manufacturing engineer, or buyer, as follows:

1. The job would be divided into basic increments.
2. A time would be assigned for each increment.
3. These incremental times would then be added up into a standard time per unit of output.
4. Standard time for all units is then matched with actual time, resulting in a concise measurement of efficiency.

This technique, known as "engineered work measurement," has received widespread acceptance for repetitive manufacturing and clerical jobs. However, serious problems develop when we try to apply the same approach to jobs involving decisions based upon complex and varied mental functions. As an alternative, many methods of work sampling and statistical analysis have been tried with some degree of success. However, since such tools often do not do the job, the search continues for better tools to measure the performance of "indirect effort" or "support" groups.

The purpose of this article is to suggest methods other than traditional "work measurement" as a means of evaluating indirect effort. It is believed that the evaluation of performance of indirect effort can be established in terms of cost return and output value. The approach centers around the following points:

1. Let us first *identify* indirect effort jobs and groups. Jobs are classified as indirect effort when they involve a certain degree of independent choice. This inevitably leads to the conclusion that indirect effort does not lend itself to rigid work measurement techniques.
2. The best approach is not to try to "measure work" but rather to adopt a more encompassing concept called Performance Review.
3. Since Performnce Review gauges the effectiveness of the manager of a group of people involved in indirect effort, the management team must originate criteria for and monitor the system.
4. By interlocking results, it is possible to evaluate the performance of related groups at various management levels.
5. Performance Review requires creative thinking at all levels. It is not a "score-keeping" device, but rather a basis for self-controlled action at each management level to reduce costs.

WHEN IS A JOB CLASSIFIED AS INDIRECT EFFORT?

The peculiar characteristics of any task in an organization place it somewhere between "absolute rote" (a fixed course or routine without attention to meaning) and "absolute independent choice" (the ability to act without restrictive influences). A representation of this "*R-I* Scale" is shown in Figure 1.

"Absolute rote" in a job is approached as an increase in the sameness of output and mental data processing occurs. Work measurement is relatively simple to apply as the "*R*" side of the scale is reached. For example, establishing the performance of various people packaging an identical marble in an identical bag is not difficult. Engineered time standards can be easily developed. Output volume (quantity of units produced or controlled over a given time) time is the most important output factor and can readily be compared to standard times.

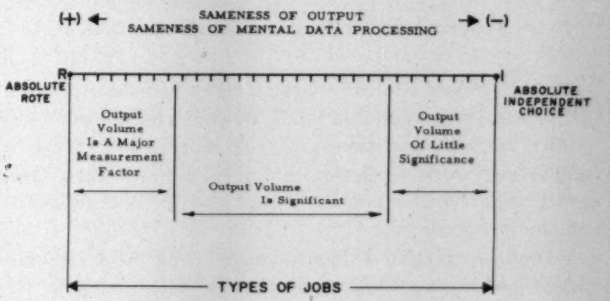
(+) ← SAMENESS OF OUTPUT
SAMENESS OF MENTAL DATA PROCESSING → (−)
R
ABSOLUTE ROTE
ABSOLUTE INDEPENDENT CHOICE
Output Volume Is A Major Measurement Factor
Output Volume Is Significant
Output Volume Of Little Significance
TYPES OF JOBS

FIGURE 1. The *R-I* (Rote to Independent Choice) Scale.

However, as we consider jobs toward the "*I*" side of the scale, other output factors creep in and minimize the importance of output volume. At first sight some of these seem to be intangible factors such as quality of decision, cost return of decision, and value of problem solving. This is because, in many tasks the *number* of units of output is not as pertinent as the *value* of output. It becomes apparent then, that Output Volume is a major measurement criterion only for a certain range of jobs.

Figure 2 places representative jobs along the *R-I* Scale.[1] This is a rough attempt to classify certain of these jobs by degree of "*I*" with emphasis on indirect effort categories. Methods of appraisal and measurement for input, output, and quality are indicated. (These methods may vary somewhat in relation to the jobs above them.)

Engineered work measurement has unquestioned application in zone *A*. Note how measurement by type of job becomes increasingly subjective as the task takes

[1] This concept was developed with Professor W. J. Richardson of Lehigh University.

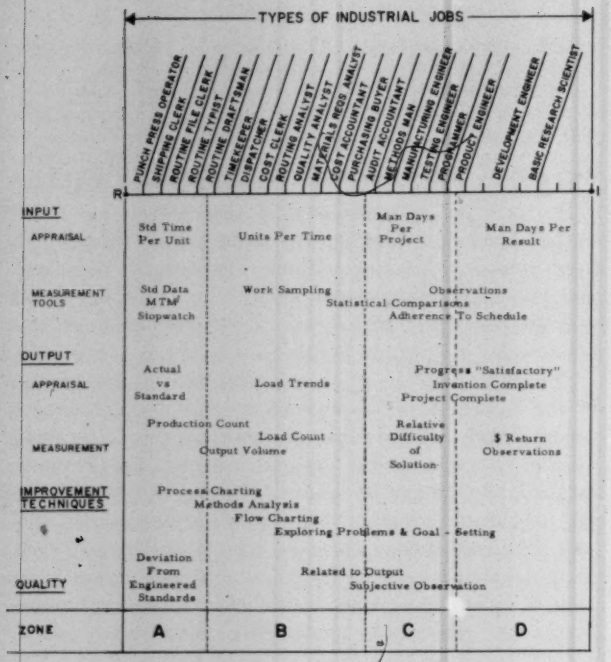

FIGURE 2. Job Types and Performance.

on "independent choice" characteristics in zones *B*, *C*, and *D*. Considering available input, output, and quality tools shown for all other zones than *A*, it is easy to see how engineered work measurement and standard work sampling approaches rapidly fall apart as "*I*" is approached on the *R-I* Scale.

Management jobs will also range along the *R-I* Scale. Their position on the scale usually depends upon the overall degree of independent choice of the group for which they are responsible.

It would be valuable to study an entire organization and assign each job to a position on the *R-I* Scale. A population count in these terms and the resulting distribution curve on the *R-I* Scale would reveal the size and extent of the indirect effort evaluation problem.

The tire plant and research laboratory in Figure 3 show two theoretical extremes. The missile manufacturer is representative of an organization faced with an extensive need for technical support.

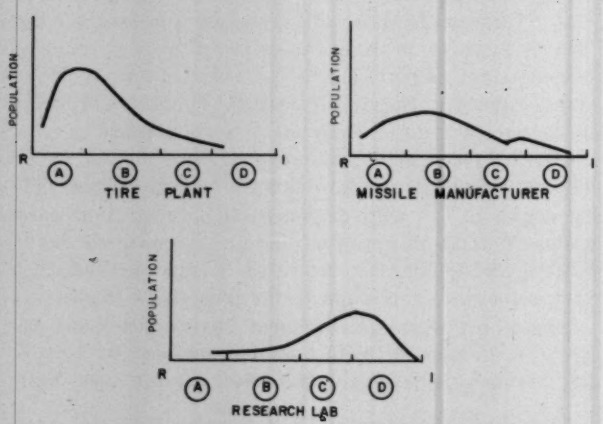

FIGURE 3. *R-I* Job Distribution Patterns.

Demonstrating an application of this concept, Figure 4 represents population distribution over all jobs in a typical manufacturing organization which requires a relatively high degree of technical and engineering support. Each job in this organization has been positioned on the *R-I* Scale in terms of independent choice.

Zone *B* in this example indicates the greatest potential for control because of the great percentage of people involved. This is typical of many industries that find their performance problems becoming more acute as population builds up in zones *B*, *C*, and *D*. We will

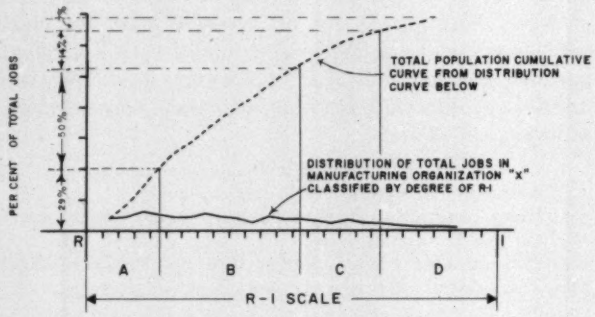

FIGURE 4. *R-I* Job Spread Analysis.

concentrate upon zone *B* since this is where the largest portion of indirect effort in industry is located, the greatest need for control exists, and the easier solutions can be found. The types of positions in zones *C* and *D* are relatively few in most industries. Evaluation of performance is a long-term matter and usually subject to the opinion of qualified management.

Many industries could profitably make a survey of this type to identify indirect effort jobs and obtain some idea of the magnitude of the control problems involved.

GROUP PERFORMANCE REVIEW

One of the obvious complications involved in the performance evaluation of any single group of support people is that the types of jobs in the group will often be spread over a wide section of the *R-I* Scale. Frequently no one method of evaluation will apply to all types of jobs in the group. A production control department, for example, may consist of production analysts, clerks, and expediters. To evaluate the performance of each individual job, as a preliminary to achieving a department evaluation, is cumbersome if not unworkable.

A more direct solution would be first to determine the effectiveness of the group, and then in terms of input, output, and quality evaluate the contribution of each

person in that group whenever this becomes necessary.

As far as running a business goes, the major aim of performance studies should be to measure group effectiveness in relation to cost. It then follows that since the functioning of an indirect effort group is the responsibility of its manager, the first objective of Performance Review is to determine the effectiveness of the group's manager in reducing costs. Once this objective is reached, higher levels of management have at their disposal a means of shifting cost-saving emphasis through their management subordinates.

The problem now becomes one of isolating basic facts pertinent to the support group, and of giving these facts weight and meaning. By working the interrelationship of these facts into a common numerical system, we can put into motion the process of Performance Review which permits all levels of management to spot and help correct the more important problem areas.

RETURN INCREMENTS

Certain observations can be made about the functions of any indirect effort group:

1. Some groups exist to provide services involving materials and facilities. Typical departments of this type are purchasing, production control, and plant engineering.
2. The function of other groups such as quality control and accounting is basically to seek out problems and solve them.
3. The performance of such indirect effort groups is based upon their ability to reduce costs while performing their mission.

There are two principal methods by which costs can be reduced:

1. By increasing the volume of unit output per employee.
2. By making other savings in direct dollar expenditures.

For example, let us assume that department "*A*" (production control) is responsible for the production analysis of materials, and issues requisitions to the purchasing department. The factors affecting cost reduction can be broken down into items which may be called "return increments." These are:

1. Ability to control more component parts and assemblies per man (i.e., ability to increase the volume of unit output per employee).
2. Ability to issue more materials requisitions per man (i.e., ability to increase the volume of unit output per employee).

TOTAL FOR DEPARTMENT	JAN	FEB	MAR	APR	MAY	JUNE
MANPOWER	20	22	23	24	23	22
RETURN INCREMENTS						
PART NUMBERS CONTROLLED	6,250	6,150	7,200	7,500	7,500	7,500
MATERIALS REQS. ISSUED PER MONTH	1,000	800	1,400	1,600	1,400	1,200
RUNNING VALUE OF INVENTORY (M$)	1,500	1,300	1,200	1,700	1,900	1,900
VALUE OF SURPLUS INVENTORY (M$)	120	120	90	90	90	90

FIGURE 5. Department "*A*"—Production Control Six Month History.

	JAN	FEB	MAR	APR	MAY	JUNE
PART NUMBERS CONTROLLED PER AVERAGE MAN IN DEPT.	313	280	313	313	326	341
MATERIALS REQS. ISSUED PER AVERAGE MAN IN DEPT.	50	36	61	67	61	55
SURPLUS AS A PERCENTAGE OF CURRENT INVENTORY	8.0	9.2	7.5	5.9	9.5	8.0

FIGURE 6. Department "*A*"—Production Control History Converted to Trends.

3. Ability to maintain minimum inventories and yet fulfill schedules (i.e., making savings in direct dollar expenditures).

Using these return increments as a point of departure, numerical trends can then be developed by a review of the department's history as shown in Figure 5. The manpower of department "*A*" consists of clerks, typists and production analyzers. These exists a certain amount of flexibility between jobs.

One of the best ways to determine the progress of the department's output volume is to convert the historical information in Figure 5 into trends per average man by dividing monthly units by total manpower. The inventory control trend can be established by comparing the value of surplus inventory[2] to the total inventory managed by the department.

Most lower level management people in charge of indirect effort departments develop reports of the type shown in Figure 6. However, these numbers can be rather inconclusive and therefore require interpretation. Figure 6, for instance, shows an increase in output volume by May, but the surplus inventory situation is alarming. Later on, inventory improves, but requisitions seem to have fallen off. A manager with several such groups reporting to him would have to ask many questions and do a lot of correlating in order to know where he can best put his emphasis.

There is a method of determining the significance of these trends. The lower level manager of the group can first establish with his supervisor the weight of each return increment. This is done by reviewing budgets, expenses, and future loads and then making a study of what the future might hold in terms of cost return. Every return increment in Figure 6 must be studied in depth. A realistic goal over a time span of one year could then be expressed in terms of cost reduction dollars for each increment. These potential savings would be assigned weights by increment. Let us assume that such a study for "department *A*" would be summarized as given at the top of the next page.

The next step is to convert Figure 6 into an index system using the starting month as 100. This index is based upon the premise that "up" is favorable and "down" is unfavorable. Figure 7 shows these indices along with each return increment weight. The surplus inventory index has been obtained by dividing January's

[2] "Surplus inventory" is the dollar value of inventory over optimum minimum inventory.

		Rounded Weight
Surplus inventories will be reduced so that the net value of this reduction to the business would be	$45,000	7
Part Numbers Controlled per man will be increased by 25% with projected cost savings of	$12,000	2
Requisition Issued per man will be increased by 20% with projected cost savings of	$ 5,000	1
Total for Year	$62,000	10

surplus percentage in Figure 6 by that of each month.

Once the goals and history have been merged in this manner, a giant step forward has been taken. It is now possible to combine all the indices in Figure 7 into a weighted single index for the entire department. This is done by multiplying each monthly index in Figure 7 by

	JAN	FEB	MAR	APR	MAY	JUNE	WEIGHT
PART NUMBERS CONTROLLED	100	90	100	100	104	109	(2)
MATERIALS REQS. ISSUED	100	72	122	134	122	110	(1)
SURPLUS PERCENTAGE	100	87	107	136	84	100	(7)
						TOTAL WEIGHT	(10)

FIGURE 7. Trends in Figure 5 Converted to Index Figures Based upon January.

its weight, adding the results by month and dividing by 10. The upper level manager can now look at the weighted trend index depicted in Figure 8 and develop a rapid "feel" for the total performance of the group. If he has several such weighted department indices before him, his attention can much more readily be shifted to the groups that most need his help.

The foregoing example is fairly representative. In terms of *R-I* Scaling, jobs in such a production control group are similar to the bulk of tasks in purchasing, quality control, cost accounting and certain departments in manufacturing engineering, product engineering and Industrial Engineering.

These principles can now be derived:

1. All indirect effort groups or departments under low level management can be examined in terms of return increments.

2. It will be possible to develop useful trend numbers and weights for these return increments, providing that the group's individual tasks do not go too far toward "*I*" on the *R-I* Scale.

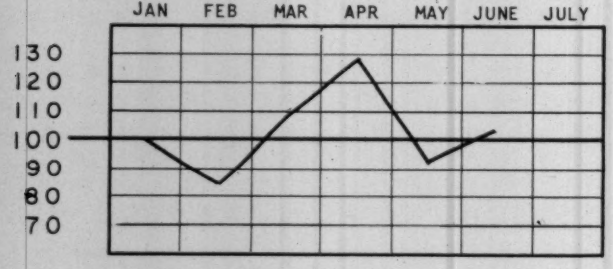

FIGURE 8. Weighted Trend Index for Department "*A*."

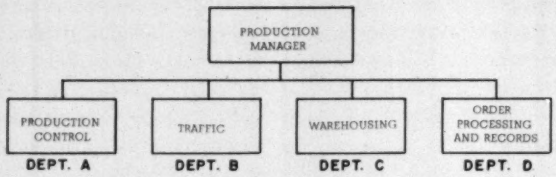

FIGURE 9. Production Control Organization.

3. A great deal of agreement has been reached and pre-analysis of the performance situation has been achieved when the lower level manager and his supervisor agree to the weight and meaning of return increments. Goals can be more easily set because of the common outlook. Follow-up is based upon mutual understanding of the situation.

4. Recording trends is a simple method of self-control which can be exercised by the lower level manager. He has conceived of and compiles a revealing "progress report" to his management.

THE DEVELOPMENT OF ORGANIZATIONAL TRENDS

Several similar departments composed of jobs peculiar to zone *B* of the *R-I* Scale will report to a higher level manager. Since there is a commonness of purpose in such organizational groupings, the interrelationship of component departments can be explored. As a result of this exploration, it should be possible to give relative weight to the potential cost return of each group.

Such an organizational structure is sketched in Figure 9. The production manager has four groups reporting to him, one of which is "department *A*."

Using the same approach as in Figures 5 through 8,

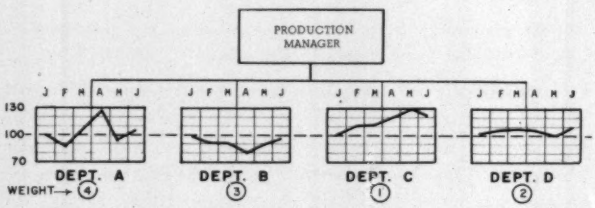

FIGURE 10. Individual Department Performance.

department weighted indices can be developed for departments *B*, *C*, and *D*.

Through the use of budgets, forecasts, and history, the production manager can develop a weight for the cost return potential of each department. These would be submitted to his superior for the latter's approval. The agreed upon department weights are shown in Figure 10. By extending these weights times each department's combined performance trend index, and dividing by ten each month, the entire production control organization performance can be computed. This takes the form shown in Figure 11. The advantages are obvious. The production control manager now has a picture of the total performance of his group, based upon a series of self-controls established by lower level managers. Performance goals and priorities now can be established with a

knowledge of the total impact upon the organization.

As the organizational Performance Review trend shows a certain percentage of improvement this can be converted into cost figures that show the approximate value of the improvement.

SUMMARY

The possibilities of computer applications to this system are extremely good. Information can be collected, "weighted" and organized into indices by the use of periodic reports transmitted to a center by lower level

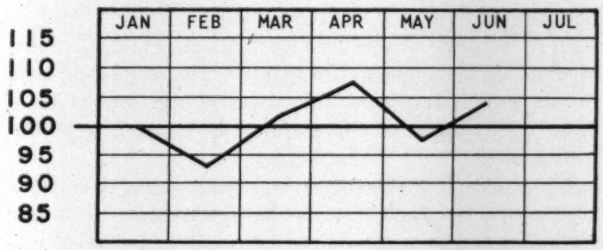

FIGURE 11. Organization Performance Weighted Trend Indices for Departments *A, B, C* and *D*.

managers. There is also a field for computer application to establish weights for return increments. The amount of computer application would depend upon the degree of sophistication vital to the system.

The advantages of Performance Review can be summarized as follows:

1. A new and large field of factual observation is opened. It is not subject to the limitations of engineered work measurement and work sampling.
2. Immediate improvement will be noted because this system will result in better understanding and communications between management lines.
3. Operating management will have a system of self-control in its possession, a system that is not originated by staff or special cost control people too often far removed from a basic knowledge of each indirect effort group.
4. Performance Review can be installed in a restricted area on a simple and limited basis. As experience is gained, the applications can be expanded.
5. As a result of better understanding and communication. a need to set more goals with non-management people will arise.
6. More reliable and scientific standards to improve the Performance Review system will be generated as experience is gained.

The Performance Review method requires a great deal of participation by operating management. It therefore becomes more comprehensive than work sampling or spotty statistical analysis. On the other hand it should be recognized that in establishing return increments and assigning weights, approximations have to be made occasionally which involve a limited amount of subjective reasoning. Comparing indices directly between areas as a finite indicator of managerial effectiveness is not to be recommended. For example, attaining a ten percent improvement in one department could require considerably more managerial skill than making a thirty percent advance in another department. Therefore the indices cannot be used as a "scoreboard" by upper management without a good deal of understanding and knowledge of the areas under this control.

The basic purpose of Performance Review is simply to ask questions that lead to improvement and for upper management to know where to lend a helpful hand. The staff man can help in the development of this system on a consulting basis, however; the generation and use of Performance Review data must always remain in the hands of line management.

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Will a Change in Name Change Industrial Engineering?[1]

by **GERALD NADLER**

Professor and Head, Department of Industrial Engineering, Washington University

CHANGING Industrial Engineering's name will be far from sufficient; more fundamental changes must be made if our activity is to survive. And even if Industrial Engineering's location is changed to the Business Administration School, will this help us unless the basic nature of Industrial Engineering is changed?

What change then should be made? I believe a change in name will be of no value if the *objective* for Industrial (or whatever name it is given) Engineering is not clearly spelled out. Just encompassing more *techniques* under a new label will not help our status in or utility to society.

I believe a change in name is needed, but for much different reasons than Professor Carrabino's (1). And I believe these reasons are crucial to the success of the change. To me, the new name and future of Industrial Engineering must be developed from the proper interpretation of the history of engineering, Industrial Engineering, and the professions as a whole. Has Industrial Engineering learned that techniques are *not* the basis for a profession? Has not the transit, a technique, nearly killed Civil Engineering? Have not the power plant and internal combustion engine, techniques, nearly killed Mechanical Engineering? And have not, first, time study and incentive plans and, now, operations research techniques nearly killed Industrial Engineering?

History, interpreted properly, *can* provide positive suggestions for making Industrial Engineering flexible and strong enough to meet any future demands.

To explain these statements, I will discuss, first, the background in which the historical review should take place, second, the history of several areas such as engineering, Industrial Engineering and business and what has been happening of importance to our problem, and, third, the practical implications of what can be done in the profession as a whole, and in the practice, education, and research of Industrial Engineering.

[1] The substance of this article was presented at the AIIE-ASEE Symposium held in Detroit, May 10, 1961.

BACKGROUND

Defining Industrial Engineering, as the AIIE has done, provides only a glimpse of where Industrial Engineering fits in the spectrum of total intellectual and industrial activities. Disciplines of intellectual content "are practiced [in] three kinds of activities: Analysis, synthesis, and reduction to practice. *Analysis* is the activity of gathering data, describing things as they are, collecting and recording instances, making lists, etc. . . . *Synthesis* is the activity of finding connections between the data made available by the analytical activity, making hypotheses and theories, and developing laws. . . . *Reduction to practice* is the activity through which a return is made from the general *principle* to the single instance. . . . It is a characteristic of . . . technology that it often calls upon many disciplines, which it then fruitfully combines (2)."

Every field has some analysis, synthesis and reduction-to-practice, but each field has its predominant emphasis. Thus, the major emphasis of mathematics and science is *analysis*. Philosophy and history emphasize *synthesis*. Medicine, law and engineering emphasize *reduction-to-practice*. Industrial Engineers are not scientists, and should not be specialists in any particular technique. *Industrial Engineers want to and should be designers*, or practitioners of reduction-to-practice.

What are we designers of? Where do we fit in society? The AIIE definition says "integrated systems of men, materials and equipment." Only cursory review will show, however, that there are many professionals who design "integrated systems of men, materials, and equipment." Consider the urban redevelopment planner, hospital administrator, legislator, theatrical producer, architect, medical diagnostician, and crime investigator. Of course, some Industrial Engineering technique can be used within these fields, but these concepts of system design are not the same as ours.

With what kind of integrated systems are we concerned? A broad view indicates that management systems of any organization are the arena for Industrial Engineering work.

L. A. Appley of the American Management Association has said, "Management is getting things done through people"; but this definition excludes the important ingredient of defining *how* these "things" are to be done. This is an important distinction, for it establishes Industrial Engineering activities as being different and separate from actual management. Industrial Engineering, therefore, is not *management*, but rather the *design of management systems*, at any level from the highest to the individual work place. Industrial Engineering should be concerned with *management systems design*, or even *management systems engineering*, and not with the management *per se* of actual ongoing systems.

PROFESSIONALISM

Industrial Engineering wants to be considered a profession. But what is a profession? Professional activity involves a high degree of fundamental understanding of the technical information used by the field, and a high degree of recognition for the social obligations of performing a service for civilization. Four criteria are suggested for defining a profession (11):

1. Rests on a systematic body of knowledge . . . and on the development of personal skill in the *application of this knowledge to specific cases.*
2. Standards of professional conduct.
3. Association of members to enforce standards and advance . . . knowledge.
4. Prescribe ways of entering the profession by meeting . . minimum standards of training and competence. (Italics added)

The first criterion is most important, but we might ask:

1. What is our body of knowledge?
2. Have we emphasized the *objectives* for application of the body of knowledge or techniques?

I do not feel these questions have been answered well by us, because our *objectives* are not well-defined.

Professions are organized by type of service, and not by technique. New areas of service or sub-objectives are added as needed; gerontology, for example, has been added to the profession of medicine because the service or sub-objective is needed. Each professional sub-area, such as pediatrics, obstetrics, internal medicine, psychiatry, and dermatology, may emphasize certain techniques or bodies of knowledge but most use nearly all the medical techniques: antibiotics, hormones, surgery, pathology, radiology, pharmacology, biochemistry, and the like. The great achievements in medicine have usually been service or objective oriented—the mastery of polio, diphtheria, or measles—these have used techniques as required. Techniques are very essential and add to professional stature, but a profession is organized by the *objectives to be accomplished.*

The legal profession is similarly organized by the objectives of its service—constitutional law, labor law, corporation law, and tax law—and not by techniques—brief writing, court presentation, and taking depositions.

HISTORY

Defining the nature of professionalism will give us broad criteria for determining what Industrial Engineering should be. History, viewed in the proper framework, evaluates what has been happening and shows how much needs to be done to reach the desired state. "The importance of . . . history . . . does not lie in any effect a study of this discipline would have on [a student's] powers as . . . a future pioneer. . . . The study of . . . history . . . [does not] sharpen a man's wit as an investigator. . . . The importance lies in the effect it will have on developing him as a person who views the whole world . . . with a broad and informed vision (3)."

Because Industrial Engineering has been intimately associated with several other fields, some brief historical background in each should help provide the proper interpretation for Industrial Engineering.

ENGINEERING

Engineering developed from a need: a job had to be done; a bridge had to be built; a lathe had to be designed; an electric motor had to be constructed; and a cracking tower had to be put into operation. And, of course, a system had to be designed to incorporate several pieces of equipment into an integrated whole.

As each engineering branch developed it took on the flavor and emphasis of a particular technique, physical phenomenon, or realm of knowledge. Thus the transits, concrete, and gravel of civil engineering; the power plants, internal combustion engines, and kinematics of mechanical engineering; and the time study, wage incentives, and production control of Industrial Engineering. Likewise, titles emphasize techniques: mechanical engineering concerns "mechanical" techniques, electrical engineering concerns "electrical" tools, and chemical engineering concerns "chemical" tools. The main interest has become *phenomena* oriented. What objective or social need is recognized in these titles? Can these areas be professional?

Engineering achieved whatever professional status it has for two basic reasons:

1. The resources and natural wealth of the country were plentiful, enabling the early practitioners or engineers to do low cost experiments and produce results with little concern for waste. A good showing was made with little effort.
2. Simple systems or *objectives* were involved. The technique orientation could be readily used to solve the simpler problems.

The need for higher mathematics and more advanced sciences or knowledge of phenomena fostered an even greater orientation toward technique. This leads to today's situation where engineers are being squeezed by two forces: application areas on one side are being preempted by "applied" scientists and on the other side by technicians. Scientists are moving into the applications vacuum left by the engineer, a sort of reversal of the growth of engineering. Industry hires physicists, chemists, biologists, mathematicians, and even social scientists to do *applied* work. Missiles, reactors, and so forth, are now scientific endeavors rather than engineering endeavors. This may not be the right approach, but it is happening. Scientists frequently feel that further theoretical work is stimulated by a closer association with application where many unknown aspects of science are spotlighted.

At the same time industry is emphasizing how important the reduction-to-practice concepts are for the future; Ford Vice-President T. O. Yntema says (13),

Most graduate students . . . are expected to learn facts and

theories and techniques . . . yet most education discourages the needed art of invention.

Engineering education is suffering from this technique or phenomena orientation. Engineering freshmen enrollment dropped preceptibly in the fall of 1958, and again in 1959 (6). Although the worst of the decline may be past, the prognosis for engineering enrollments is not too good. One can see a high school student's thought process: "Why should I be an engineer, or a pseudo-scientist, when I can study science and become a real scientist?" Educational institutions are asking a similar question: Is there a necessity for maintaining engineering schools?

In so many cases, the engineer has come to this situation because he does not conceive of his having a role or objective in society; he only applies techniques.

INDUSTRIAL ENGINEERING

Taylor's time study in manufacturing plants started Industrial Engineering. The other pioneers are primarily noted for the development of techniques: incentives, motion study, predetermined motion time systems, Gantt Charts, etc. Ask any management man or even layman what he thinks Industrial Engineering is and the universal response will involve some technique: "motion and time study," or "incentives," or more recently, "linear programming." Compare this image with that of medicine or law. One would seldom get a recitation of techniques; rather the responses would involve the total objectives of the health and care of a patient, or of the protection of the rights of individuals. In many ways, the Industrial Engineering image is worse than that of the engineering field as a whole, where the reaction may result in a statement of objectives, such as "He builds things or objects (4)."

Management's view of Industrial Engineering has resulted in mopping-up assignments for most Industrial Engineers: The costs are too high for the machining operations, therefore motion and time study are to be applied; there is too much overtime in department X, and cost reduction techniques are needed; scrap levels have become too high and quality incentive plans should be tried; inventory costs are too high therefore operations research is to be applied. Is the technique really what should be used? When is Industrial Engineering used for design purposes?

The new techniques are not changing this image. Industrial Engineering in some industries and universities is becoming statistics, mathematical programming, computers, or a combination of these. These are techniques. University Industrial Engineering departments are trying to teach courses in the basic techniques. A mathematician or a statistician is best qualified to teach these courses; our students are short-changed when engineers or similar personnel teach these topics because they are given an applications base rather than a mathematical or more fundamental base. Why do Industrial Engineers feel they can teach such courses—"matrix theory, set theory, theory of stochastic processes, sampling models, analysis of variance, design of experiments, decision theory, discrete variable theory, . . ." (actual listing of material one Industrial Engineer said he felt competent to teach). Other fields, such as electronics, transport processes, instrumentation and controls, and applied mechanics, do *not* claim to teach the mathematics they require for their applications—partial differential equations, complex variables, Laplace transforms, and so forth.

These new techniques are not changing the image of Industrial Engineering for several reasons:

1. They are still tools.
2. They have far broader usefulness than in Industrial Engineering only.
3. Because Industrial Engineering departments cannot usually afford a well-qualified man in each new technique, some Industrial Engineer who has learned a little about the technique teaches the topic.
4. A qualified person usually does not want to join an Industrial Engineering department where his total range of usefulness is restricted.
5. The new emphasis on tools gives even less thought to the design functions of Industrial Engineering.
6. Industrial Engineers who have pioneered in teaching some new techniques, like computers or statistics, have become reluctant to get more areas in the engineering school or the university interested in using such techniques to permit the best, most knowledgeable person in the technique area to be hired.
7. Industrial Engineering departments which emphasize such techniques will eventually be asked to justify their existence because their subject matter is already being taught in the university.

The degree to which so many Industrial Engineers have clasped the new techniques to their bosoms as the means to solve all problems can only remind one of the same grasping originally accorded to time study. It too was supposed to be industry's panacea, solving all the problems of the day. We know now that the emphasis on the *technique* of time study was wrong; too many other factors had to be considered, and, most important, little emphasis was placed on the total objective for the system as a whole—the beauty of the time study model was overwhelming. To me this appears to be the identical state of affairs in relation to today's "beauty." We have again glorified a set of techniques, and, in so many papers, industries, and research, have not been concerned with our purpose.

And, to compound the danger of this idolatry, the new techniques do not "belong" to us. Time study is a technique which at least was claimed by one prime group—Industrial Engineers. But the new techniques are so broad that they never have been and never can be peculiarly those of Industrial Engineering, although they are essential to present Industrial Engineering. Statistics, computers, linear programming, simulation—these are

used now and will be even more so in the future by all engineers, by economists, by sociologists, to help find answers for their *realm of objectives.*

Industrial Engineering's preoccupation with technique has allowed some of its application objectives to be taken over by others, just as has happened in other engineering branches. Who are the human factor engineers? Psychologists. Who are the administrative scientists? Sociologists. Who are the "systems and procedures" men? Accountants and controllers.

The history of comments concerning the shortcomings of time study should also remind us to heed the shortcomings of "our" new techniques. Many operations research techniques, for example, are mainly non-dynamic, linear, and non-stochastic, not at all characteristic of the dynamic design work which should characterize Industrial Engineering. Some progress, though, is being made, dynamic programming and non-linear programming for example.

In addition, the name "operations research" implies another difficulty; analysis of operations or activities *now going on.* The correct inventory level, for example, is viewed differently by production, sales, purchasing, and financing. Operations research finds solutions by manipulating mathematical models of inventory levels, rather than the real-life inventory levels. The overwhelming concern for mathematical model construction presumes that *how* the activities are performed is to become the status quo within the model. The models are then manipulated *to optimize the status quo* methods and systems; far too often operations research optimizes what is available rather than designs a system to better accomplish the objectives. Operations research is frequently located in the comptroller's office because the workers there have access to all parts of the organization for *collecting data,* thus emphasizing that data about existing systems are the principal food of operations research. Perhaps Peter Drucker makes the most telling point when he warns that "what can be quantified is usually irrelevant (5)."

Thus, Industrial Engineers receive the continued assignment of "mopping-up" rather than design activities. Could operations research be our new time study?

BUSINESS ADMINISTRATION SCHOOLS

Some historical comments about business schools will show how the emphasis on techniques in Industrial Engineering must be changed. In most cases, business schools, or related institutions, have an orientation toward *objectives.* They have established strong relationships with top management in business because of their objectives, even though they have not usually developed or used quantitative *techniques.* The severe criticisms of business schools in the Gordon-Howell and Pierson reports are mainly in the area of academic qualifications (11): "Low academic standards, low admission requirements, low-calibre students, inadequate facilities, superficial teaching . . . and neglect of research." The business schools were assailed "within the terms of their own cardinal objectives of career preparation and service to business." Those institutions, like Harvard, Carnegie Institute of Technology, and Massachusetts Institute of Technology, which received praise for their programs, have the same objectives but reach them with much better students, staff, and techniques. Although scientific and mathematical decision-making tools and great emphasis on the behavioral sciences were recommended, the *objectives* for education and application remained the same.

Will the business schools, with these new techniques, shift from the objective of training managers to the objective of *Management Systems Design,* which I believe belongs to Industrial Engineering? Perhaps they will, because Industrial Engineering has not clearly staked out its objective. Several prominent business schools (like Northwestern, University of Southern California, and Indiana) have already started programs with the new techniques. One university calls its offering "Production Management and Industrial Engineering," for which National Defense Education fellowships have been provided. These new programs also show that new techniques are not basic to Industrial Engineering.

Thus, the history of business administration schools shows how important it is to have objectives clearly developed to permit long-term growth as a profession. Perhaps some Industrial Engineers view techniques and phenomena as our objectives but I am convinced that this is not our proper role.

RECOMMENDATIONS FOR INDUSTRIAL ENGINEERING

The historical evidence indicates, it seems to me, rather definite courses of action that should be followed by Industrial Engineering. Most important is that most of the suggested actions can be taken *today* to prepare the way for meeting any situations in the future

The question, then, is how this new image can be created and implemented. The action to be taken seems to fall into four categories:

1. Professional
2. Application
3. Education
4. Research

PROFESSIONAL

Industrial Engineering must establish its purpose in life and must establish its objective as *Management Systems Design.* This would include all systems, such as production and management controls, and would utilize all techniques. We can no longer argue the merits of whether production techniques or operations research techniques are to be the basis of Industrial Engineering.

One set of techniques needs the other in Management Systems Design. We cannot be scientists or mathematicians. We must be designers.

The importance of establishing the Management Systems Design image cannot be overemphasized. What is more, management of any size or type of activity seems eager to accept this objective. In the past few months, for example, five organizations, with from 250 to 14,000 employees in activities like hospitals, department stores, manufacturing, and telephone service, have consulted me about installing certain *techniques,* specifically standards, scheduling, work measurement, operations research, and plant layout. When I discussed these requests with the presidents, vice presidents, and committees of the board of directors, it became apparent *in each case and to each of us* that the technique *per se* was not what was required, and that the philosophy of Management Systems Design was what was needed. Of these five organizations, one has established a Management Systems Design staff department, two have made Management Systems Design their Industrial Engineering department's objective, one has changed its training courses toward this objective, and the fifth has put all its supervisory and executive personnel through orientation sessions on Management Systems Design.

The name of Industrial Engineering should be changed to Management Systems Design, Management Systems Engineering, or, as Carrabino suggests, Management Engineering. Much will depend on the action taken in the professional recommendation. The change in name, however, comes *after* the most important concept has been identified—the need to have an objective. The name should not be changed just to include more techniques.

The definition of Industrial Engineering needs to be changed, but this should be easier than changing the name. Thus, the key phrase could read: "Design, improvement, and installation of integrated *management* systems."

Basic functions and sub-functions should be promulgated. Rather than emphasize techniques Management Systems Design should emphasize old and continually develop new functional areas of practice. The realm of new possibilities is large: organizational control, administrative systems, human factors, packaging, military administration, research and development, and so forth. Old areas need to be reviewed to determine how a better job can be done and how the subjects can be taught better. For example, quality control is usually taught as a series of techniques. Why not teach quality assurance as a system to be designed before production starts, as well as one to be utilized after production is started? Heavy emphasis on techniques with almost no concepts of designing quality assurance systems has created the strange situation where very few Industrial Engineers are employed in the quality assurance and control field.

Management Systems Design needs more inter-disciplinary background in actual industrial practice. More sociologists and psychologists need to be used in designing systems. Biologists and philosophers should also be used much more. I do not mean that these disciplines should be consulted occasionally; I mean that they should be considered an essential part of all Management Systems Design activities. This will change many organization charts, and may well mean that some smaller companies must cooperate to bring such rigor to their own activities.

Where should Management Systems Design be located —in engineering, in business, or in the liberal arts? Industrial Engineers have been proud to be a part of the engineering field, their only home. Most suggestions for a name change include engineering, even Management Systems Engineering. Today, however, managements have a restricted concept of what engineers can do in the total organization. Even high school seniors have displayed this feeling. The engineers' restricted view was noted by Sir Charles Snow in the last of three Godkin lectures on "Science and Government" at Harvard University in December 1960, when he said (14):

> Engineers—more uniform in attitude than one would expect a professional class to be—tend to be technically bold and advanced but at the same time to *accept totally* any society into which they may have happened to be born. (Italics added).

The only alternatives to being a part of engineering are to become a part of business administration or of liberal arts. However, Management Systems Design has its own needs and qualifications which can help make the decision: It needs a very rigorous educational climate. At the present time, rigor in areas of importance, such as mathematics and sciences, is more prevalent and student entrance requirements and faculty levels of competence are higher, in engineering. I would suggest that Management Systems Design stay in engineering, *but engineering as a whole must change if we do stay.* If it does not, business administration is the only other real choice for a reduction-to-practice activity.

But what changes should be made in engineering? The engineering framework must group areas of common knowledge and permit more flexibility in establishing undergraduate and graduate degree programs. The challenge has been presented to engineers by others (9), who point out that the present divisions of engineering are really accidents of history and are now mainly meaningless. Three ways to view engineering might be considered: as practitioners of know-how or skills, as scientists, or as professionals fulfilling a social need. Although each has its problems, the third is by far the best because it is truly professional and it is more flexible.

Washington University's School of Engineering is undergoing reorganization to achieve this third goal. Classical departments will be eliminated, and in their place will be departments stressing and coordinating previ-

ously scattered areas of basic knowledge: thermodynamics and transport processes, structures, electrical fields, materials, mechanics of solids and fluids, instrumentation and automatic control, human and organizational factors, engineering mathematics, environmental systems, and systems engineering to coordinate large-scale project teaching and applications. The usual engineering degrees, however, will be awarded, but new degree offerings can be arranged easily and changed as the needs indicate. Thus as civil and mechanical engineering are dropping out, new programs can be arranged quite easily by selecting them from among the various common-knowledge areas. As an illustration, majors in industrial management, human factors, management science, and manufacturing engineering can now be offered more readily in addition to the Industrial Engineering (Management Systems Design) major.

This broad view of engineering can almost certainly make it become the center of the University, where all the sciences and disciplines join forces in conversion-to-practice. Even the design aspects of business administration will be more suitable in such a framework. Because Management Systems Design must depend on rigorous mathematics, natural sciences, social sciences, and selected business administration topics, the new engineering program is most suitable for it. And, even if engineering is not the place for Management Systems Design, it must involve the rigor of these areas.

Techniques must be properly utilized. Present Industrial Engineering techniques should now be structured to portray the Management Systems Design orientation. Why do we need production control? It should be production systems design. Why should we have quality control? It should be quality assurance systems. Why should there be motion and time study, methods-time-measurement, or standards? They should be Work Design (7) (8). New areas (like gerontology in medicine) and techniques (like operations research) can be easily added as needed without disrupting the framework. Because all the techniques, mathematical and non-mathematical, are for *analysis*, especially *for learning* about operating situations, they are a part of *Management Systems Design*. As a matter of fact, organizing our field with such objective orientation helps lead the way toward developing more techniques and application areas. Instead of only exploiting existing techniques, such organization would provide opportunities to present challenges to others in the organization to assist in developing techniques. Objectives are far less likely to need replacement.

How Management Systems Design can help society must be emphasized. We should not remain secluded. Management Systems Design activities should be portrayed as a service to society, and this view must be presented to all types of organizations. Each individual should take an active interest in schools and educational problems, which are frequently Management Systems Design problems. The Management Systems Designer should serve on community boards and committees to portray his general knowledge of society and how his profession can serve the community. This concept would make sense to laymen; they can grasp this objective just as they have grasped the objectives of the medical profession. The titles of a computer specialist, an operations research specialist, a motion and time study specialist, or even an Industrial Engineer do not enlighten the public about the profession or how the individual can serve the public and society.

APPLICATION AND PRACTICE

These concepts can be put into practice rather easily. The dual basic objectives of a management system—to increase productivity (even in automatic factories) and to develop the effectiveness of people—must be the guides for all activities.

1. A Management System Design department should be organized around objectives and not techniques. One old Industrial Engineering department, for example, had sections like methods, incentives, maintenance, and standards. Thus three or four *different* Industrial Engineering staff members visit each operating area to accomplish the application of its *technique*. This is rather foolish; only one person or one group organized to accomplish the *total objectives* should be in contact with one operating or staff area. The coordinating central office should have its own technique specialists to provide a check and balance system for (a) assisting the engineers operating in the field, (b) determining the effectiveness of the engineers' total applications, and (c) checking how well their specific techniques are being used.

2. Management Systems Design reports should give less emphasis to techniques. They should emphasize objective orientation, showing how the proposed system structure accomplishes the objectives of the project and the organization. Too often, reports are submitted on the basis of "the application of technique A."

EDUCATION

1. Technique should be taught clearly labeled as such. Thoroughness in and knowledge of the technique should be emphasized, but the technique should be represented as one *means* to the total *end* of the profession. More modern quantitative techniques and additional science should be added to the program.

2. Design concepts should be taught in a coordinated course where the techniques must be *used*. This should be in addition to any preceding component courses, such as management control systems, management systems simulation, and work design.

3. The history of Industrial Engineering and all intellectual activities should be taught to emphasize how future actions can be contemplated by proper interpretation of the past. Merely reviewing the chronological sequence of events is useless. In addition, most Industrial Engineering history is taught in terms of technique development (Taylor developed time study, Gilbreth developed therbligs, Gantt developed loading charts, etc.); instead, such teaching should stress the *objectives* of studying work and productivity.

4. Management Systems Design departments should *seek* interdisciplinary relationships within the whole university. A joint program, for example, with sociology on technology and culture would help achieve 3. above.

5. Every effort should be made to have the basic techniques

taught by qualified personnel in that technique or science, even within the engineering school. The Washington University engineering school, for example, has a mathematical statistician interested in application, thereby providing better and more inspiring teaching in depth for *all* engineers. More time could then be spent developing the new design areas to help meet the total objectives of Management System Design. The time could even be used more fruitfully in considering basic questions, such as the need to have a five-year program.

RESEARCH

Research in Management Systems Design, or even in engineering as a whole, should develop knowledge about the range and boundaries of applicability of basic laws to the general situations we face for which designs are needed. Research might establish optimizing principles for classes of problems: What is the optimum storage space to be allowed between two operations? What is the range of usefulness for a specific economic lot size formula? What special formulations of statistical techniques can be evolved to assist the Management Systems Designer operating in the field? The dividing line between our research and basic scientific research for investigating basic, natural, physical, mathematical or social sciences is fairly well defined *for the profession*. However, it may be quite hazy for one individual in Management Systems Design who is interested in developing a new queueing model for multiple-channel requirements; he may be performing some basic mathematical research.

1. The avenues of research in a Management Systems Design program are literally unlimited. Many new areas must be "opened up": industrial research, product development, management controls, information handling, organization theory (5), packaging, organization planning, safety, and materials management. *How* Management Systems Design concepts can be applied in these areas needs outstanding research.

Such research can make a real contribution by establishing the required basic image. Can Management Systems Design do good research in computer programming or in game theory? Not really; the field can, however, do excellent research concerning the application of these concepts to new areas and to extend and improve old areas of applications.

2. How is the Management Systems Design process carried out? Is the scientific method the correct approach for designing? Washington University has established an interdisciplinary research group to investigate the conversion-to-practice process; this is the most important aspect of our field. Mathematical tools cannot be applied to anything until some system specifications are available or have been designed. Linear programming, for example, must be applied to assumptions or specifications related to a system; the design of the system must precede the use of linear programming.

3. Interdisciplinary research should be undertaken in all the new and old areas. Just as practitioners must use more of the basic sciences, Management Systems Design research must seek the participation of the natural and social sciences and the mathematicians rather than trying to do its work alone.

CONCLUSION

The objective of Management Systems Design must be the reason for a new name and a new image. Combining techniques, like the "measurement-oriented elements of the controller's function, Industrial Engineering, and operations research (1)," into a new name will not be a long range answer.

Our history and that of other professions provide the answer. Medicine is firmly based on the sciences, yet it is not all science. Law is firmly based on jurisprudence, yet it is not all jurisprudence. The ministry is firmly based on theology, yet it is not all theology. Industrial Engineering can be the same type of profession, based firmly on the sciences and mathematics, yet not all science and mathematics. It is design, it is Management Systems Design or Management Systems Engineering. "The scientist is primarily a thinker, the engineer a doer (10) (12)."

Rallying around Management Systems Design will eliminate the battles of defining Industrial (or management) Engineering: is it motion and time study, or production control? Is it incentive plans or quality control? Is it job evaluation or tool design? Is it production processes or operations research? These are techniques, all used within the realm of Management Systems Design. By providing such a focal point for the field, it will grow.

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Recollections of H. L. Gantt

by **WILLIAM E. CAMP**

Former Chief of Staff and a Director of Wallace Clark and Company

This article was contributed by an associate of Mr. Gantt.—L. G. TABER, *Chairman, Gantt Centennial Committee.*

DURING the years of Mr. Gantt's consulting practice, there were one or more young men in each of his client's plants who were dedicated to him and his principles. They were employees of the client company, also they were intensely loyal to Gantt, and their prime interest was seeing that his methods were successfully installed. They gave all or a large amount of their time to implementation, instructing and training. Later on, Wallace Clark, who was one of this group in the old Remington Typewriter Company, formalized this relationship in his own consulting practice. He called them (perhaps for want of a better title) "understudies," and he required the client to appoint them for the duration of his contract. The system saved the use of "juniors" on Clark's staff, thereby saving money for the client; and it left one or more thoroughly indoctrinated men within the client organization after the consulting arrangement terminated.

The writer was fortunate in being available to serve as "understudy" to Gantt in his clients' establishments for a period of several years. The first such assignment, as a young engineer just out of college, was with the Remington Typewriter Company. Alford's biography of Gantt points out that the Remington engagement was notable for the fact that, largely through the influence of Fred J. Miller (general factory manager), it was here that Gantt mellowed and changed his personal behavior from that of a "firebrand" given to explosions and "bawling out" to an attitude of tolerance and patience, though still insistent and uncompromising in fundamental principles. Alford says:

> This change in Gantt is remarkable for the fact that he was forty-nine years old when he began to work for Remington. That he did change, and change so decidedly, is evidence of the fundamental soundness of the man, of the elasticity of his mind, of his ability to efface himself, control his own emotions, and unite his personality with the group in which he was working.

My term of employment with Remington covered the period during which the change was taking place. I was witness during a working day to an explosion and a bawling out, but the same evening at his hotel he undertook to teach me the tolerant and patient technique. My fellow workers at Remington stood in fear of "Uncle Henry's" periodic visits and were glad that they were not invited to dinner and the evening with him. I soon came to know, however, that the evening would be quite different and a most valuable experience.

A typical evening reflected his leadership, his desire to teach and help young men and the loyalty and deep respect on their part. The following will illustrate:

His hobby of quail shooting in the south was discussed.

On my criticism of a fellow worker, "He is young and new. He does not realize that the more you know, the more you know there is to know." He drew a short line on the back of an envelope. This represented what a man now knows, but it is also the radius of a circle and in revolving it touches a circumference of unknown. A gain in knowledge of one inch (on the envelope) increases the unknown by six inches.

Or again—the colored retainer at the plantation met Gantt at the railroad station.

"Massa Henry, where you come from this time?"
"From New York, Jackson."
"Is that furder away than Richmond?"
"Yes, lots further."
"Furder than Baltimo?"
"Yes, lots further."
"Lawsy, I didn't know the world *was* so big."

There was his hobby of the study of military strategy, the reading of passages from a book on the strategy of Stonewall Jackson and diagrams of a battle area on the back of another envelope.

He showed me a letter he had just received from the president of a large and nationally known manufacturing company in Ohio, asking him to come out and discuss the work for the company. When I asked when he was going, he replied that he would write him to "read my book." And to me, "He (the president) doesn't understand what it is all about." I have always remembered that as evidence of complete professionalism. He certainly was not conducting a sales campaign for more business!

One man in a client's office had spent a lot of time designing a procedure to take care of some part of the production control. It was a hard way of doing something which did not need to be done. I had tried to stop him.

As an example of the change to patience:

> Let him go ahead. If we clamp down on him, he will keep it in his desk, cherish it and bear us a grudge. If we let him use it he'll soon find out it's no good and stop of his own accord. Then it will be thoroughly out of his system.

The change which Alford notes had been completed.

There were, perhaps, fifteen young men at that time who gathered around him at each annual ASME meeting in New York, in groups on the lobby floor, listening to his papers and lively discussions at the meetings, lunches at the Engineers' Club. For them he superseded the "one dear professor" in college.

Henry Laurence Gantt in Retrospect

by **F. D. MANNING**
Senior Consulting Engineer

This article was contributed by an associate of Mr. Gantt.—L. G. TABER, *Chairman, Gantt Centennial Committee.*

THE contributions of Henry Laurence Gantt to scientific management may be measured by comparing what he did with its effect on the thinking of management in the early nineteen hundreds. At that time, the goal in plant operation was a maximum utilization of labor, at low wages, and a minimum of overhead or indirect expense.

Mr. Gantt, like many other engineers for management of that period, worked on the utilization of direct labor. His task and bonus plan, which need not be described in detail here had two significant factors:

1. His piece rates were figured in terms of standard hours. He used time as the common denominator.
2. He developed charts to visualize for management daily operator performance, showing whether each operator made bonus (black), failed (red), or was not on piecework (x).

The gradually increasing preponderance of black measured the improvement in utilization of direct labor and contributed to the realization by management that, with sound incentives and organization, high wages could produce increased productivity and lower unit costs.

These charts showed that labor, at times, did not reach its full potential and, by analysis, the causes for failure were largely beyond the control of labor, further, that utilization of machines was involved.

This led to his Idle Machine charts which classified and standardized the causes of idleness into five basic reasons and established, again using time as the common denominator, a measurement of the responsibility of a specific phase of operation. The causes were:

Lack of:
Repairs—which has now developed into Preventive Maintenance.
Help—Personnel Department.
Materials—sales forecasting, purchasing, inventory control.
Orders—sales.
Planning.

The costs of these failures were emphasized by use of Machine Hour Rates applied to the idle hours.

At Chevey Brothers, the use of Machine Hour Rates on the operators for manufacture of American flags, considered a solid profitable item for slack times, disclosed that they were in fact an operating loss at current prices.

The effect of the Idle Machine charts was to direct the thinking of management to its responsibilities and to give an impetus to planning.

Mr. Gantt then concentrated on the development of his chart which was, in effect, concentrating on problems of management rather than on utilization of labor. The planning technique which eventually emerged had, using time as the common denominator:

Central planning against capacity to produce.
Decentralized departmental planning according to schedules or scheduled orders issued by Central Planning.
The Gantt Chart.

The Gantt Chart, which visualized the planning and recording of actual performance against plan provided a tool by which management could envision how it was functioning and take remedial action.

The evolution of the Gantt Chart obviously did not occur as smoothly as described above. It came from parts and contributions in the development of his ideas in many places. The acceptance and spread of its use into its present many ramifications testify as to its worth.

A comment by Mr. Gantt shortly after the introduction of his chart will bear repetition. He said that women grasped the principle of the chart better than men because they looked at it without preconceived ideas, and men could tell him more ways to improve his chart after studying it for five minutes than they could after a half hour. What he meant then merits consideration today.

During his lifetime he was considered by many as quite radical, he was, in the thinking of engineering and management of that era. But the test of time has proven the soundness of the principles he advocated.

He had two staffs. The first left him to contribute to the war effort of World War I. The second staff, formed after that war, had worked under his direction using his charts in the Ordnance Department, Shipping Board and Emergency Fleet Corporation and had been recruited from the plants of his clients which included Celluloid Company, De Laval, Remington Typewriter and Chevey Brothers, among others.

This staff was with him until his untimely death. Among that second staff he was never thought of, or spoken of, as other than "Uncle Henry" which reflected the mutual relationship. "Uncle Henry" was a stern taskmaster. He knew just what he wanted done and expected his instructions to be followed. Failure to do so resulted in a dressing down which was remarkable for its comprehensive content in so few words. On the other side, he was an exceedingly kind man, who, by thoughtful acts and advice, was always encouraging and developing his staff.

This article was contributed by an associate of Mr. Gantt.—L. G. TABER, *Chairman, Gantt Centennial Committee.*

Henry Laurence Gantt[1]

by **FRANK H. NEELY**
Chairman of the Board of Directors, Rich's, Incorporated

IN THINKING back to my first meeting with Mr. Gantt, I am reminded of my trepidation in approaching a teacher and preceptor who had for several years, through reading and study, been my ideal. Upon the meeting all shyness and timidity vanished, for I found myself in the distinguished presence of a man simple, kind, gracious, generous, eager to be of help in the quest for an understanding of the industrial world and the place of each aspirant in its evolutionary development.

Such was my experience in about 1914. I was 29 and Mr. Gantt was 52, but he made me unconscious of any disparity in years or experience. He was sympathetic and desirous to know of my needs; and, on subsequent meetings, I was "glorified" that he had become my friend. He always had available time and attention and thought on my behalf.

Mr. Gantt's influence made him, in my estimation, the world's greatest Industrial Engineer in management. This was because, besides having a new mechanism of management, he had in addition superb human understanding, as well as a comprehension of the elements of our financial and business systems.

For example, the development of Mr. Gantt's philosophies claimed his attention in a series of stages:

Improved Work Methods. This science ran the gamut of all kinds of improvements that were preliminary to the workman and his machine's turning out the maximum amount of product with the greatest ease—making the most wages—and with the least fatigue.

Responsibility of Management and Ownership. Mr. Gantt sensed that, no matter how skillful and efficient the worker may be, his efforts come to naught unless the owners have a balanced investment in plant and equipment, backed by capable management for production and distribution.

Over-All Managerial Improvements. Mr. Gantt believed in over-all managerial improvements rather than more scientific and specific directions in limited areas.

Mr. Gantt stressed to all associated with him that when any change is made, the habits of the worker and the management should become fixed in the new method. Installing an innovation and relinquishing it before new habits are formed rarely are justified in final accomplishment. For this reason Mr. Gantt seldom would take his efforts and organization into a plant for the purpose of improvement unless he had a long-time contract. He was of the opinion that no improvement could be permanent until habits had been set with both manager and worker. He abhorred pseudo-efficiency engineers who would go into a plant, write up a grandiose report, file it with the management, collect a fancy fee, and go happily on their way. Psychologically, an improved method should create for the worker *a pride in his skill and a joy in his accomplishment*. This consummation comes only with sufficient training time to acquire the new habit of work.

In the reorganization of any factory, Mr. Gantt felt the necessity everywhere for the elimination of waste and idleness. Training a few men to high efficiency was not sufficient for a smoothly run shop. He stated that a scheme of development of the efficient must be supplemented by a plan that would train the inefficient as well and put the idle to work. This, he claimed, would be more dramatic if we changed our cost-keeping methods to reflect the expense of idleness, whether that idleness be involved in men or machines.

In 1915 at the ASME meeting in Buffalo, Mr. Gantt expressed in beautiful and precise language a deep thought which has become axiomatic in the training of young managers and engineers.

> It is better to do inefficiently that which should be done than to do efficiently that which should not be done.

Henry Laurence Gantt's conceptions—some large, some small; some emphatic, many tenuous—will continue to influence engineering and management and the operation of our great nation in its countless radiations because they contain human understanding coupled with a comprehension of the elements of our financial and business systems.

[1] Excerpts from the Address of Acceptance, by Mr. F. H. Neely, when given the Henry Laurence Gantt Gold Medal Award (1952) before the American Management Association and the American Society of Mechanical Engineers.

This article was contributed by an associate of Mr. Gantt.— L. G. TABER, *Chairman, Gantt Centennial Committee.*

Some Recollections of Henry Laurence Gantt

by **HENRY VAN RIPER SCHEEL**
Consulting Engineer

AS FELLOW-STUDENTS at Stevens Institute of Technology, Hoboken, New Jersey, Frederick W. Taylor (1883), Henry L. Gantt (1884) and G. M. Sinclair (1884), whom Gantt succeeded as Taylor's assistant in 1887, must have become well acquainted. Probably well known to them all, too, was Maunsel White (Stevens Institute of Technology, 1879), who, with Taylor, created the first alloy-steel high speed cutting tools capable of doing two to four times as much work when employed on lathes, planers, drill presses, shapers, and the like.

No doubt also well known to all these men was William L. Lyall (Stevens Institute of Technology, 1884) whose father and uncle, as young men in the Civil War days, had established the machine building firm of J. and W. Lyall and also the Brighton Mills, a small cotton mill located on West Twenty-Third Street in New York City. Then most recently Brighton Mills had established itself as the originator and first producer anywhere in the world of *cotton* fabrics for pneumatic tires for bicycles and automobiles.

In June 1895 Taylor read his paper "A Piece-Rate System and Shop Management," and in June 1903 his "Shop Management" before the American Society of Mechanical Engineers, and, as President of ASME, in 1906 his "On the Art of Cutting Metals." By this time, J. and W. Lyall, in anticipation of a greatly enlarged demand for their cotton tire fabrics, had moved the Brighton Mills to Passaic, New Jersey, where William L. Lyall, as President and Treasurer, was in charge.

Lyall had familiarized himself with Taylor's ideas as described in the "Shop Management" papers and, after hearing "On the Art of Cutting Metals" asked Taylor whether what had just been talked about was something which might be helpful in a cotton mill. Taylor thought a cotton mill might be helped but suggested that Lyall go to his classmate Gantt who was very familiar with all that Taylor had been doing.

Although Lyall could not have imagined there would be available for his cotton mill anything as "major" as a new kind of steel for metal cutting tools, with specific instructions for heat treating the metal (so that the carbon in the steel would cut like a diamond instead of being a sort of molecule-lubricant like graphite in a lead pencil) and with a Barth slide-rule to help decide optimum speeds, depth of cuts, etc., Lyall could and did feel that "minor" developments like Taylor's "Belt Standardizations" and the "Employment of Running Water at the Cutting Tip of the Tool" would have their equivalents in a textile mill. Furthermore, active in an industry where so many decisions were being made rule-of-thumb, Lyall had come to feel that there was great merit in the making of a scientific analysis of any operation or problem and then the determining of the "one best way" which—as a continuing standard—could be used for the fair scoring and/or rewarding of daily performance.

In 1908 Lyall retained Gantt as consulting engineer and engaged me to look after, for Brighton Mills, all of Gantt's workings.

The details of the methods and practices introduced at Brighton Mills are shown and described in Gantt's book *Work, Wages and Profits.* In the ten year period of his services to Brighton Mills (Mr. Gantt died in 1919) his task and bonus formulae and methods were applied to practically everybody at the worker level either individually or in groups. Indeed, the excellence of services to and the expertness of the workers were so continuously satisfactory, we were worried a little at the gossip traceable to outside unfriendly critics that unless enough work was produced the mill would "fine" a worker for non-performance.

As is well known, Mr. Gantt's feeling had always been that if an employer had a worker listed on his payroll, the worker ought to be paid at least a fixed daily minimum amount no matter how much nor too little the measured performance of that employee had been.

At the time, it was felt and argued that Gantt's "task and bonus" was more humanitarian in its operation than, under certain circumstances, the differential piece-rate could be said to be.

During this period, the production capacity of Brighton Mills was increased from 35,000 to 450,000 pounds per week and the ever-increasing pressures, on the one hand, of larger and more complex deliveries which were being demanded, and, on the other hand, the needs for having at every working point enough, but not too much of all materials needed to avoid the "losing of the bonus," these pressures resulted in a need for most careful attention to the scheduling function because, for instance, at high production rates, a small miscalculation might result in the filling up of all the empty spools in a department with unwanted yarns.

In accommodating to these pressures there was devised and tested in use the graphical system which, now in quite general use here and abroad, has come to be known as the Gantt Line Chart. This system displayed the quantities available relative to the quantities as planned and scheduled ahead of time *in units of time,* i.e., per day or per week; and doing so in such group and sub-group arrangements as made clear what element in a group was laggard or ahead of schedule.

In 1909 when the Boston attorney, Louis D. Brandeis, was about to become so nationally well known because of his argument on behalf of the public before the Interstate Commerce Commission, he and Gantt spent much time together in the preparation of the case. Brandeis was going to argue that a requested increase in freight rates should not be approved until and unless the railroads had given themselves the benefits of the new management philosophy and methods being successfully applied in so many different industries.

Since I was to be a "textile mill" witness, Mr. Gantt suggested I come to New York the Sunday evening before the week of hearings in Washington to become acquainted. On arriving at the Great Northern Hotel, I found Gantt and Brandeis in deep discussion of what the new principles and practices should be called, having been listed: "Taylor System," "Taylor Methods," "Advanced Management," "Scientific Management," "New Management Methods," "Progressive Management" and others. When I left late in the evening, no decision had been reached but on the next and following days Brandeis repeatedly used the term "Scientific Management" and thus established the appelation as standard thereafter.

* * *

Before the United States entered World War I, General Crozier, Chief of Ordnance in Washington, sent for Mr. Gantt who was doing consulting work at the Frankfurt Arsenal and told him that our getting into the war was inevitable and that Gantt should plan his consulting services accordingly. Gantt asked what Crozier would like him to do and Crozier responded "You ought to know what is needed; do that!"

So, Mr. Gantt suggested that communications could be expedited and improved and it was arranged that I should look after the reportings from Rock Island Arsenal.

With the excellent cooperation of the arsenal personnel, the Gantt-type charts for reporting the schedulings and performances of all the single items, subassemblies and completed units supplied by or through the arsenal were kept up to date on a daily basis as to entries. Then on Saturday afternoons all sheets were photographed and prints sent to Washington. This reduced the time for transmitting written data from three to seven weeks to three days.

Hearing of this accomplishment, the U.S. Shipping Board invited Mr. Gantt's attention to the matters of more efficiently handling the ships in the South American trade and of shortening the turn-around times of ships in port. Wallace Clark effected tremendous savings by the application of graphical planning and scheduling procedures to the operation of ships and a graphics chart system which I devised, installed and for months supervised was soon reporting at daily or weekly intervals what every hatch of every ship in every world port was doing every hour of the day or night.

In two important respects the influence of Henry L. Gantt continued long after his passing—indeed, even down to the present day. For not only did the professional accomplishments, for which he is so justly admired, repeat and extend themselves to an extent not anticipated by him or anybody else; but his manly qualities of character, his patience, persistence, resourcefulness, leadership qualities, generous fairness and adherence to principle through the months and years have been an inspiration to many of us.

This article was contributed by an associate of Mr. Gantt.—L. G. TABER, *Chairman, Gantt Centennial Committee.*

Henry Laurence Gantt—Industrial Conservationist

by **ARTHUR L. SVENSON**

Professor of Management, Graduate School of Business Administration, New York University

CONSERVATION of resources has always been a major concern of industrialized countries. In the United States, husbandry of these resources—land, raw materials, capital and manpower—attracted little sustained management interest until the years surrounding the turn of the century. During that period, the Scientific Management movement began directing our attention to the reduction and elimination of industrial waste, particularly waste in the production processes.

Henry Laurence Gantt was responsible for moving our conservation emphasis from the production floor to the full scope of the business enterprise itself. Later, as the result of his governmental activities in the World War I production effort, Gantt expanded his conservation thesis to include industrial activity on a national scale. Gantt was one of the first international management theorists to recognize the essential relationship between economic conservation and social health.

Gantt understood that industrial effort had to support and further community well-being. Industry survived only as it furnished economic goods and services which the members of society at large wanted and considered valuable in satisfying their needs. Gantt warned industrial managers that if they failed to add to the sum of the national wealth through provision of these goods and services, society would take over the operation of the industrial sector.

It was characteristic of Henry Laurence Gantt's humanism that he focused his conservation activities on the industrial worker. In devising his work methods and later his theories of management organization, Gantt never departed from his accent on people. Conservation of human effort was for him the key to the fruitful use of all other enterprise resources.

Two examples drawn from the work of Gantt highlight this emphasis. The first is his insistence that wages be adequate to sustain normal living standards and sufficiently high to win the interest and participation of the worker. The development of his task and bonus system of wage payment stresses this relationship of employee to company goals.

The second example is Gantt's statement that the value of a business is not a matter to be equated in terms of dollars, but rather it is to be equated in terms of how well the organization of people work together for mutual survival. As the business enterprise is able to draw its people into a common discipline and understanding, corporate value, expressed through economic use of resources, is increased. Without this identification, membership friction results in wasteful practice which squanders those very resources upon which national safety and health rest. But most wasteful of all is the misuse of our vital, scarce human resource.

As industrial conservationist, Gantt was inevitably led into the area of management organization. Moving from technical organization, which occupied his early years as a management consultant, he came to appreciate the greater role played by general management. In his last years, Gantt addressed himself to this core problem of industrial conservation: the organization of management.

Gantt's thesis was that the organization of a company was more than the sum of its component parts. The concept of independence of component parts did not adequately explain the whole of a business enterprise as it sought survival in a social and economic environment wherein change was the dominant characteristic. Organization of management also had to change to keep abreast of these varying demands. Only through the intelligence and participation of men in the organization could this be possible.

Gantt perceived organization so structured as to release the talent of company men; the human element, he felt, was the only creative resource to meet the challenge of change. Management, therefore, had to recognize that each member was "a human unit in a living organization." Without this recognition, individual knowledge and judgment could not be brought to bear on the

demand for economic performance. In order to have industrial effectiveness, the men of organization had to be free to exploit their creative abilities.

Exploitation for Gantt did not mean the supremacy of one man over another, the driving of workmen by unreasoning imposition of will and power. Gantt deplored supervisory practices which employed these tactics. Exploitation meant to him the creative use of human talent and effort to further enterprise goals and to add to the sum of national wealth and security. This was Gantt's elegant solution to our country's need for sustained, increased industrial productivity.

Gantt pointed out that industrial conservation cannot tolerate favoritism and privilege in organization. New life, new ideas, new blood had to be constantly infused into the business. These together with an organizational climate conducive to personal growth supported the goal of industrial democracy. Thus in our individual companies and in our nation, we promote industrial citizenship by centering organization on the living problems of living people. Only in this manner can we husband democracy's resources.

Gantt cited idle manpower as our primary recurring waste. His contention was that as we tolerate this inefficiency, we corrupt the very foundation of industrial life. Gantt was not only referring to unemployment as such. He was speaking of the waste we tolerate of employed men whose skill and judgment are greater than the contributions expected of them.

For us today it is interesting to note Henry Gantt's concern for the conservation of time. His stress on two elements—human effort and time—underlay the strategy of the Gantt chart, which later was internationally popularized and refined by Wallace Clark. While the mechanics of the chart include machine loading, routing, dispatching, man-machine ratios and functional activities, the factors of time and effort bear the conservationist's dynamic emphasis. It is logical that Gantt should have stressed in his chart this primary linkage of time and people. These two elements were the sustaining motifs in all of his work; they were the dominant features of Gantt's drive toward industrial conservation.

Gantt proposed that industrial leadership be assumed only by men who had knowledge of resources' capabilities. In any other hands, waste would characterize the employment of these resources. Industrial leadership is a continuous exercise in conservation. This leadership has to be demanding—a fair day's reward for a fair day's work—if social benefit is to be experienced. Further, the direction given by our industrial leaders requires that maximum output of production be derived from minimum input of resources. Gantt knew that managerial fat, waste in the top echelons of organization, made operational activity wasteful, too; knowledge only, not rank warrants the designation of leadership.

In times of national crises, the ability of leaders to conserve industrial resources is crucial. If we recognize this need in time of war, Gantt felt that we had every right to demand it of our peace-time industrial leaders.

The aspect of Henry Laurence Gantt as major conservationist in the industrial sphere has not yet been fully appreciated. We tend to see first Gantt's methods of work, and later his production coordination activity of World War I. Still, in his early work, the ground was being prepared for his emphasis on conservation of industrial resources.

Gantt went far beyond the original Scientific Management movement to eliminate waste in industry. Such waste is, after all, a by-product of deeper managerial maladjustment. Gantt applied engineering concepts to an unexplored area of enterprise life—the economic use of resources at the disposal of the company and of the nation. Of these resources, Gantt rightly saw that man himself is the leading, the inventive, the expandable resource.

In industrial conservation, Gantt was our pioneer. Slowly perhaps but certainly, we begin to understand the full stature of the man.

READER COMMENTS

MEASURING MANUFACTURING PERFORMANCE, by T. G. Hughes, *Journal of Industrial Engineering,* November-December, 1960.

As usual, I read with interest the November-December, 1960, issue of *The Journal of Industrial Engineering.*

I would like to call your attention to the article by Mr. T. G. Hughes and especially to the following:

"There is hardly a company today that does not employ some type of incentive wage system as a means of obtaining peak performance from its direct labor workers."

It ill behooves an Industrial Engineer to make such erroneous statements.

I am enclosing, for your information, the November, 1960 issue of the *Collective Bargaining Report* which shows that only about 25 per cent of manufacturing workers work under some form of incentive system. Actually, the number of employers using some type of incentive system represents a distinct minority. I often wonder why Industrial Engineers, who are supposed to be concerned with proper statistical procedures and with fact finding, make such wild and unsupportable statements. Maybe this is the reason for the low professional status of Industrial Engineers generally.—*Bertram Gottlieb, Industrial Engineer, Department of Research, American Federation of Labor and Congress of Industrial Organizations.*

WORK SAMPLING—ELEVEN FALLACIES, by Harold O. Davidson, *Journal of Industrial Engineering,* September-October, 1960.

"Fallacy" No. 6.

While agreeing in principle with the notion of an optimum sample size, the detailed appraisal suggested of each activity in a study is not really necessary, nor is it possible in many cases to assess the "cost of additional data and returns gained from improved precision."

The author, quite rightly, points out that the importance of an unproductive activity with respect to its effect on overall efficiency, is related to the amount of time spent on it. He then proceeds to the argument that in order to obtain the same precision of estimate, relatively, of a small percentage than on a larger, we have to increase our sample size.

If the first part of the statement is true, is it not also true that the precision of estimate required for a small percentage is not so important as that of a larger?

A suggested approach is to calculate the number of readings required to give a selected precision and confidence interval for the activity which has the most effect. This will be the one whose value is nearest to 50% of the total, because the expression for the number of readings

$$N = \frac{kp(100 - p)}{L^2}$$

N = Number of readings.
p = Percentage activity.
L = Limits of accuracy.
k = Number of standard deviations to give desired confidence.
Assumes a maximum when $p = 50$

$$\left(\frac{dN}{dp} = 100k - 2kp \text{ equated to zero gives } p = \frac{100k}{2k} = 50\right)$$

Thus, if the activity whose value nearest approaches 50% of the total is used in calculating the number of readings to give the desired precision and confidence, it is a fair assumption that the rest will be within acceptable limits, as any other percentage would give a smaller N.—*C. Gledstone, 2 Moorside Gardens, Eccleshill, Bradford 2 Yorkshire, England.*

AUTHOR'S COMMENTS

It appears that the initial discussion did not make its point with sufficient clarity. The observation that increased sample size is required to maintain a constant relative precision of estimate as the estimated proportion, p, decreases was a statement of fact. The argument was felt incomplete since it appeared that the reader would easily infer the conclusion stated in the comment, i.e., "the precision of estimate required for a small percentage is not (in general) so important as that of a larger. . . ." In this matter, then, there is no difference in viewpoint between the original article and the comment.

There does, however, seem to be a difference of view with respect to the fundamental point of the discussion; namely, the use of arbitrarily selected "precision" criteria for sample size. The approach suggested in the comments does not really avoid this problem. Since $\frac{L}{k} = \sigma$, an arbitrary selection of L and k would not seem necessarily better than an arbitrary selection of σ. It is easy enough to define k as the number of standard deviations to give "desired" confidence, but to determine in a rational way what confidence he should "desire" one is still forced to an appraisal of economic consequences. Admittedly, the appraisal may be crude but to suggest that it is impossible is to imply that one knows very little of the value of the data he proposes to collect or of the collection costs. The frequent occurrence of these conditions should perhaps be regarded as symptomatic of insufficient attention to the definition of problems and planning for efficient utilization of the Industrial Engineering staff.—*Harold O. Davidson, Vice President, Industrial Engineering, Operations Research Incorporated.*

THE METAMORPHOSIS OF INDUSTRIAL ENGINEERING INTO MANAGEMENT ENGINEERING—PLEA FOR CHANGE IN NAME, by Joseph D. Carrabino, *Journal of Industrial Engineering,* January-February, 1961.

This is equally as much a statement of my findings and beliefs as it is in reply to Carrabino's article in the Journal.

Metaphors and Industrial Engineers

Several Industrial Engineering societies have evolved during the past twenty-five years, a period covering my interest in Industrial Engineering as a profession. The AIIE is the one to achieve national recognition and status. This growth and prosperity came not entirely, but largely because of basic philosophy and fulfillment of a professional need. Strong membership qualifications and effective leadership were very close in order of importance to this growth. Physical transformations and change are lived with by the Industrial Engineer. Change, per se, is avoided or handled with caution.

REGISTRATION OF THE INDUSTRIAL ENGINEER

Professional registration and strict requirements for member status are strongly related in the engineering founder societies. Over 20 states include professional licensing of the Industrial Engineer in the registration programs. The part of AIIE in the satisfying of, or preparation for, current licensing is obscure; in

California, however, all AIIE Chapters are represented in the action and compose the organized forces for registering. It is clear that a change of name, such as to management engineers, will nullify present prospects.

Engineer licensing, a good, consonant framework of membership requirements, and the broad scope and purpose of AIIE satisfy those interested in the practice of the full sphere of Industrial Engineering activities. The Member Industrial Engineer finds no need to emulate "small critters," chameleon or others; he is able to change hats and he has unqualified imitators. An Industrial Engineer is alert to changing times and finds his practice requires a mind adjusted to flexibility of need in commerce and industry. This does not appear to indicate a need to adopt a new name.

CHANGING TIMES

Trends toward automatization of the factory and the process industries have forced attention upon mounting costs inherent in increased size of maintenance staffs. Rising costs of hospitalization and disparity in numbers of indirect to direct workers in industry has focused attention in these areas. Service and banking and insurance firms are distressed by rising costs and the expense of space in which to situate clerks. Result: Industrial Engineering techniques have now been found to be equally, and even more dramatically, useful in these activities than in the management-dictated earlier devotion to the levelling of labor costs. Early or late, effective Industrial Engineering performance combines engineering, psychological and mathematical considerations not normally identified with other professions. The Industrial Engineering profession is dynamic.

TRAINING

Broad internship is normally essential to capable engineering performance. This background is accelerated by appropriate training, academic and situational. Unfortunately, academic or business experience does not serve well all who are exposed thereto. Consequently, some fail to qualify in one field, but find proficiency in another. Others do not adjust even with retraining. This differentiates and distinguishes in many ways. It also frustrates, irritates and gives rise to a variety of expressions.

The tendency to change that which is otherwise beyond reach is natural and is an emotion to which we are all exposed. It is by no means restricted to engineering groups, nor to baseball and the contested and unwanted third strike—called!, nor to the crossing of a lane and "fouling" in track. Each thing cries out for a change; none with quite the total professional impact of the Metamorphosis—January-February, 1961 issue of our *Journal*. The article serves a purpose. It awakens! It should aid toward consolidation of that which we have.

AN ANSWER

Caveat emptor is more than a sign; it is a guide. It should be heeded before the AIIE buys a "change of name" to management engineering. Much more is to be lost than can be recovered through and by virtue of relaxed membership criteria which would surely follow. Increased quantities of members would not appear equal to maintenance of present standards plus professional status, plus present objectives. The positive impact of Industrial Engineering disciplines and techniques is recognized internationally.

When real need exists, it can be met. Several alternatives present themselves as possible solutions to any problems of identification of activities covered by professional groups. The ASME has a management division, among others, but retains the mechanical engineer name. AIIE has choices if action is dictated by facts, among which are:

1. Set up a Management Engineering Section.
2. Consider Human Engineering as an interest area.
3. Establish a Standards and Work Measurement Section.
4. Evaluate the need for a New Techniques Section.
5. Establish a Section For Academic Coordination to work with ASEE and other groups; assist to standardize Industrial Engineering curricula.

THE HORIZON

A metamorphosis or change of the other type would undoubtedly result in the early formation of a new Industrial Engineering complex with membership requirements suited, as are those of AIIE, Inc., to an engineering profession. Failure to accede to change may result in the formation of a management engineering society, replete with membership requirements which are fitted to less technical criteria.

It is noted that one national association of management engineers (ACME) exists. Another could be formed to accommodate those unable and/or unwilling to meet the membership requirements of AIIE. However, such members could find satisfaction in one of the foregoing AIIE alternatives.

If true organization happiness or benefit is available without a real and active interest in the group to which one belongs, it has escaped my attention. Some belong and support, while others lend their thoughts and energies, but many kinds compose a membership. Frustration is not uncommon to any walk of life, nor is disappointment; but it appears more plentiful if energies are misdirected. Consequently, criticism and discontentment result and upon occasion, precipitate a call for relief.

Members of AIIE should review and evaluate the causes of, and the losses inherent in, change before acceding to or making any awkward changes. To go on from here and to meet and to lead the expanding horizons without making unworthy sacrifices should continue foremost among our goals. The Industrial Engineer is catalytical—let the Institute show this, continuing its dynamic and useful growth. A premature crossing of a metaphorical bridge would lead us to the unhappy conclusions that we have within the AIIE that which we traveled far to find. Let us practice conservation and eliminate the waste and the cost engendered by the metamorphosis.—*C. W. Whitston, Department of Industrial Engineering, University of Southern California at Los Angeles.*

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DEAR DR. CARRABINO:

May I congratulate you and offer my support to the proposal outlined in your thought-provoking article "The Metamorphosis of Industrial Engineering into Management Engineering—Plea for Change in Name" which appeared in the January-February 1961 issue of *The Journal of Industrial Engineering*.

You quoted a letter from an outstanding member of the AIIE who stated that "the government people write very narrow job descriptions and base all of their write-ups too much on the word Industrial. . . ."

I am a member of the AIIE and a government employee with more than twenty years of service. The author of the letter quoted above pointed out a very obvious deficiency in job descriptions related to the "Industrial Engineering" series. The AIIE committee, which contributed so much to the Civil Service Commission in establishing a series of standards for Industrial Engineers, apparently further confirmed the findings of the author of the quoted letter. There still exists some points of difference between the AIIE committee recommendations and the Civil Service Commission in the series definition and specifications for the job title "Industrial Engineer."

As an example, one particular field of government work has been reclassified in title many times without any major changes in the basic job. This job is also presently identified under three different titles across the United States. These titles, Industrial Engineer, Production Specialist, and Industrial Specialist cover the same line of work.

With the tens of thousands of engineers serving the government as civilians and military, the leadership of the AIIE for such an undertaking is dictated by the confusion that exists and need for corrective action. The lack of cohesive thinking is evidenced by the variety of professional field(s) identified under one nomenclature and, conversely, the same field(s) identified under several functional titles. Your proposal, therefore, would have widespread effects upon industry and government. The variety of governmental functions—from the initial research and development efforts to ultimate procurement of end items and related production equipment and plants—encompass many directly related activities. These run the gamut of Industrial Engineering, as presently and narrowly defined, to a widespread variety of managerial, technical, and production functions as outlined in your article.

There is an urgent need for a change in nomenclature; not only as it applied to industry but to the government as well. Your sound solution to this problem is timely and factual, and will have a long range effect upon the future of the Industrial Engineering profession if action is taken now as you propose.—*Paul A. Longo, 63 High Hollow Road, Roslyn Heights, Long Island, New York.*

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As a young engineer I am in agreement with Professor Carrabino in his plea that the name of our society should be improved but I am disturbed over some of his ideas for our future, which although of the best intentions may fail to look at realities.

As he sees it, our Society (and I believe the word Society is more appropriate than Institute) with a new name would then be able to become some sort of a management spokesman. In a statement by President Rathe in the same issue, Dr. Rathe said that an Industrial Engineer covers a triple field: work measurement, production control, and quality.

So much for what it supposedly is now and what it might be in the future. Now I should like to cover some history. The founding society encompassing management and Industrial Engineering is the American Society of Mechnical Engineers of which both Gantt and Taylor were esteemed members while developing the scientific management concept. For various reasons the AIIE was formed as sort of a splinter group. The "feuding" has continued by the formation of the two societies covering quality control and inventory and production control.

Why has the AIIE failed to fulfill its objectives as outlined by President Rathe so that two other societies had to be formed to cover two of the three functions of the AIIE? We might find the answer by deciding why the AIIE was formed from the ASME. If it were because Industrial Engineering was too big a field to be part of a society, then maybe the two new groups feel the same way of their fields as related to Industrial Engineering work measurement. If the AIIE can't do an adequate job of meeting the needs of the profession as outlined by Dr. Rathe, then how can we expect to do a good job by extending into "management engineering"?

I believe that before we can expand our fields and continue to encroach into the ASME management division, we must put our "own house in order." Our situation is not unlike the Protestant revolution now going on whereby years ago churches were set up whenever slight differences occurred. Now they are realizing their error and are reconsolidating. Should we not also? Should we not make the AIIE the only spokesman for the three divisions of Industrial Engineering, and then and only then look into related fields for expansion.

Besides feeling that Professor Carrabino's AIIE objectives are premature and wishful thinking unless we do something to correct our own current weaknesses, I am not overly sold on "management engineer" as the best title. He feels the word "industrial" is weak. I feel the word "engineer" is, today, almost as weak, and particularly so when modified by an adjective which could be used by every supervisor today if he so desired.

Until a man has made a name for himself, the only title that means anything anymore is "professional engineer." All other engineering titles can be used by any one in any engineering department whether he be a draftsman, designer, or engineer. After a man has made a name for himself, he doesn't need a title. I strongly doubt if the title "management engineer" is going to mean much once the term starts to catch on and every supervisor uses it.

What then should we call our society? We might use Taylor's idea by calling it the American Society of Scientific Management. However, this encroaches on the Institute of Management Sciences, and it is desired to separate science from engineering.

The name American Society of Industrial Management brings in the operational and engineering idea and overcomes the weakness of the common use of engineer by so many. However, the word "industrial" is weak for a professional group although when linked to the word "management" it is stronger than Industrial Engineer.

I believe that the word "management" is a far stronger word than "engineer" in the eyes of the public. Therefore it should be the noun in any title. A title of American Society of Engineering Management accomplishes this.

The name ASEM is as strong by another viewpoint. No one will ever have a title "engineering management" so that the society will not be linked to any particular group such as AIIE is linked to only Industrial Engineers. It would be a society of a profession, composed of Industrial Engineers, management engineers, mechanical engineers, etc.

However, before we prepare for expansion into new fields, let us first consolidate our position so that one society represents all Industrial Engineering, rather than three different groups, for in unity there is strength.—*Thomas T. Taber, Box 164, Muncy, Pennsylvania.*

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I heartily endorse Professor Carrabino's "Plea for Change in Name" in the *Journal of Industrial Engineering*. I believe that the intense desire to retain the traditional name that so many of our most prominent Industrial Engineers evince is inspired by exaggerated fears of the predicted loss of professional standing. This is particularly true of those Industrial Engineers with the best training from the highest types of engineering schools, because the aim of those schools is solely directed to training engineers for state certification. Because the best Industrial Engineers have been imbued with the feeling that individual certification is vital to professional standing, it is often assumed that this would be good for the profession. This is a real hindrance, as I will show.

Examine the reasons for certification. In my analysis there are two: one that pertains to engineers and other designing or operating physical systems, the other to those who work within a codified social system.

In the case of engineers, the reason has always been safety of life and property because of the dangers inherent in the engineering product. The public has a right to insist that designers of potentially dangerous objects be skilled in safe design. It does so insist by a combination of qualifying examinations and experience requirements.

Look at the historical record—the designer of a collapsed railroad bridge is publicly excoriated and an inquest is held over his professional grave, while the designer of a railroad whose customers stay away in such droves that it must be supported by the state is held in no lower professional regard for that.

In the case of codified social systems, the public insists that those who will use those systems present evidence of knowing the contents of the code. Certified public accountants, lawyers, residential electricians and truck drivers are so certified. The original reason for writing the code *may* have been safety, but

once codified the physical reasons for the rules are ignored and the enforcement is by the rule book.

There are those few groups who have managed to ride the coat tails of those going before and have become certified through the public's negligence. Observe the undertakers who have become certified as *morticians*. The old saying starts "Doctors bury their mistakes. . . ."; how do we differentiate the morticians' mistakes, and is it of any importance? In consequence the professional pretensions of morticians are but laughing stock.

I hold that the province of the Industrial Engineer lies neither in dangerous physical systems nor in codified social rule books. In fact, if we get anywhere near either, we are far from the path of duty. With the first, we are exposing the workers to undue hazard, and should consult a Mechanical Engineer for a safe design. With the second, we would be stifling progress by restraint of trade, and do you think that we, of all people, believe that's right?

Our province is the design of integrated, flexible, social-cum-physical systems to accomplish productive results. Flexibility is vital, because we cannot operate where either the social rules are so rigid that new procedures are outlawed, or where the physical system is so close to its limits that operability or safety completely determines the system.

Our future, yours and mine, lies in this work. We must expand our abilities to cover the goal, or be content with time study hackwork. We are now members because our interests (and abilities) are above this minimum. The name our association bears should connote our interests, while because of the history of 30 years ago the present name conceals rather than edifies. Let us therefore devise and adopt a better name.—*John Forester, 2837 Domingo Road, Fullerton, California.*

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Apparently Professor Carrabino is not familiar with an article which appeared in the March-April 1960 issue of the *Journal*, entitled "The Management, Engineering and Scientific Function," by Harold O. Davidson. This article presented clear distinctions between the functions named, and illustrated the dangers of trying to perform management functions by using scientific or engineering methodologies.

I agree with Dr. Davidson's thesis, and therefore I disagree with Professor Carrabino's case for the name "management engineering," since it represents a contradiction in terms almost as bad as "scientific management" and "management science." But Professor Carrabino is right in his assessment of the broad scope of activities now carried out under the too narrow term "Industrial Engineering." The objectives of similar professions, such as operations research and management science, are not basically different from those of the Industrial Engineer, or at least those of the well trained Industrial Engineer who has kept pace with the latest techniques and philosophy. It seems that one term could appropriately describe the work of these professions, and I agree with Professor Carrabino that the need for such a term is not a trivial matter.

As an accurate consolidation of the terminology in question, I believe there is a strong case for the name *operations engineering*. Perhaps the best argument appears on the back cover of each issue of the *Journal*. If one merely substitutes "operations engineering" for the first two words of the standard Industrial Engineering definition it becomes a definition of engineering activities in business operations, military operations, governmental operations and institutional operations as well as industrial operations.

Being more specific, the definition would cover, for example, weapon systems analysis, logistics, traffic enginering, the engineering approach to financial operations, and engineering methods applied to hospital procedures and inventories.

Yet in spite of its broad scope, operations engineering is a relatively precise and easily understood term. The word "operations" makes a reasonable distinction between the engineering of hardware (or chemicals), which is the function of other fields of engineering, and the engineering of operations involving integrated systems of men, materials and equipment.

Of course, "operations engineering" is not a perfect name (in the sense that it wholly defines an exclusive set of activities) any more than "physics," "chemistry," or "electrical engineering" are perfect names. Nor does "operations engineering" carry the aura of prestige suggested by terms involving the words "management" and "science." But I believe that "operations engineering" is an honest and practical name for a profession that should be characterized by honesty and practicality.

It can be argued that there is nothing more impractical than an attempt to change the label of a profession or several professions. I do not labor under the delusion that any such change will be effected soon or ever. But I am convinced that this debate over terminology is a necessary part, perhaps the focal point, of any attempt to clarify and remove the schisms that presently divide our professional societies and adversely affect our professional status.—*Cecil R. Phillips, Jr., 4703 Saul Road, Kensington, Maryland.*

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As an Industrial Engineer serving a retail establishment, I have been acutely aware of the problems covered in Professor Carrabino's article in the January-February issue of the *Journal*. Even within the organization (and the department is twelve years young here and started three years earlier at the parent Marshall Field and Company), I still occasionally face the problem of explaining my title and function. This is perhaps due in part to the fact that the "elementary" phase of work simplification passed its peak of usefulness about five years ago.

Most surprising however is the number of fellow Institute members from manufacturing concerns who express surprise to find Industrial Engineers working in nonmanufacturing concerns. These fellows, who decorate their Industrial Engineering badge with a string of "PACE," "PEP," "PERT," etc. medals like a marksmanship badge will be most difficult to convince we need a change of name. Industrial Engineering fits their work measurement activities well.

I have experimented with outsiders who ask my line of work by referring to myself as a Management Engineer and have found this much less difficult to explain, and have yet to be trapped into the, "Oh, you mean efficiency expert" that so frequently follows an explanation of "Industrial Engineer."

As you can guess, I will be one of the quickest to switch badges to "Management Engineer" when AIIE is ready to switch theirs.—*Robert A. Boyd, Manager, Industrial Engineering Department, Frederick and Nelson.*

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INDUSTRIAL ENGINEERING OR MANAGEMENT ENGINEERING?

In an article in the January 1961 *Journal* Professor Carrabino discusses some of the changes that have taken place in Industrial Engineering and recommends 1. that the activity henceforth be described as management engineering and 2. that appropriate education be centered in schools of business administration rather than engineering. The topic is a most timely one—both engineering education and graduate education for business are in the process of critical evaluation—perhaps a few further remarks on the subject would not be out of order.

There is no question but that the character and content of Industrial Engineering has markedly changed in the last decade. I suspect that present and future undergraduates who are advised into Industrial Engineering as a refuge from analytical, quantitative work by people who were familiar with Industrial Engineer-

ing education when it was undeniably the least quantitative of the engineering curricula are in for something of a surprise. The change lies in both in the attitude and methodology espoused and the problem area which is considered. It is this job enlargement of Industrial Engineering that has created some degree of overlap with business administration. As long as the Industrial Engineer concerned himself with the mechanical design of the production process and the measurement and improvement of individual productivity his relationship to management was fairly obvious. However, when he begins to direct his attention to the design of comprehensive and integrated production systems and/or information processing systems the relationship is much less clear.

I believe that the basic distinction is that the Industrial Engineer is interested in the *design and construction* of a production system but *not its operation*. I am not denying that the specification of certain operating disciplines is as important to systems design as the specification of hardware—but the engineer does not expect to personally operate the machinery he designs or execute the rules he devises. Many engineers do, of course, eventually become involved in operation. When they do they are administrators or managers and no longer practicing engineers. Many people with engineering background, both in education and experience, are eminently successful as managers but it is not the purpose of the present remarks to debate the efficacy of engineering education for this type of activity. The important point is to recognize that Industrial Engineering training is to prepare a man to create, rather than operate a production system. Industrial Engineering today is concerned with larger systems than in the past—systems which will be operated by a manager rather than a machinist—but the role of the engineer remains essentially the same.

It does not seem reasonable to me to expect schools of business administration to train this type of engineer, whatever name is used to describe him. In fact, it seems somewhat inconsistent to choose a new name which includes the word "engineering" and at the same time argue for an educational home outside of engineering. I don't doubt that a graduate school of business can take a matriculant with a quantitative undergraduate training in science or engineering and provide the desired type of training—if it is willing to spend the time and acquire the faculty that is necessary. I am very doubtful that this can be done in a reasonable period of time with students whose undergraduate background is essentially qualitative. To admit that a graduate school of business could achieve the desired end result with students of appropriate background is not to concede that this is the only way this can be accomplished or necessarily the most desirable way. Regardless of what was the case in the past, today there is no reason why Industrial Engineering education must depend upon one of the more traditional areas of engineering to instill an appreciation of the design process, or the "engineering method," or the theoretical and experimental comparison of alternatives. There exists a body of knowledge of adequate depth, scope and rigor to enable the field to stand on its own. The necessary discipline of thought and method of analysis can be achieved within the area of application, and I believe that a student educated in this manner will have a significant competitive advantage in engineering practice in this field. There is a small, but growing number of universities which are committed to the education of a quality, modern Industrial Engineer at the undergraduate level in parallel with the more traditional specialties.

On the other hand, business schools, in their task of educating a man for a career in management, are going to have to convey an appreciation of this field. The manager is going to have to call upon this specialty for help, supervise this work, and evaluate quality. The relationship is not unlike that of the manager with his specialists in law or in product research and development. I believe that there is a substantial difference between achieving appreciation and achieving the depth and competence necessary to practice in the field.

The name that is associated with a type of activity is certainly not as important as the nature of the appropriate education, but still worthy of comment. Presumably the incentive to change the name from Industrial Engineering to something else arises from the feeling that there is an unfortunate public image connected with that name. Specifically, while the field has changed in recent years, the public image has not. Yet this is typical of any field in which there is progress and not a strong reason for changing the designation. It is not at all clear to me that it would be an easier task to explain to the public what is meant by the new *X* engineering and how this differs from the old Industrial Engineering than it would be to explain the same activity as a new aspect or dimension of Industrial Engineering. People in operations research have been engaged in this pursuit for some years now and I still get the impression that some of the listeners are not convinced. Obviously, no one adjective is going to be able to encompass all of the activities that can reasonably be identified with a particular field. I suspect that "industrial" does about as well as any and, in fact, it is probably more appropriate today than in times past when its practitioners had a narrower field of vision. In particular I would not exchange it for "management" engineering. Management engineering does not seem to be more descriptive of the area of interest, and certainly does not serve the purpose of dissociating the field from the past. There have been curricula in management engineering before and to the best of my knowledge, neither their record nor their image is any more distinguished than that of Industrial Engineering.

In summary, it would be nice if the public—particularly those portions of the public who advise prospective students, and those who hire graduates—understood the present character of Industrial Engineering. But I don't know how shifting to a new and unknown name would aid in this cause, and shifting to a name that has been used before and has a history and connotation of its own would certainly not help. I should note that while it is certainly true that employers and recruiters are not uniformly aware of the metamorphosis of Industrial Engineering, if our experience at Cornell is any indication, there is no problem in placing graduates in challenging positions that take full advantage of their education. The problem is much more that of providing a sufficient number of graduates to meet the specific requests of employers who know precisely what they are looking for. Furthermore, I don't believe that the problem will be in any way alleviated by shifting the burden of education to schools of business administration. I would be delighted to see a continuation and extension of the present trend to increase the quantitative content of business curricula. An enhanced appreciation of recent quantitative developments on the part of management can only increase the opportunities for modern Industrial Engineering.—*R. W. Conway, Department of Industrial and Engineering Administration, Cornell University*

PRESIDENT'S COMMENTS . . .

by **ALEX W. RATHE**

President of the American Institute of Industrial Engineers, 1960-61

Industrial Engineering and Science

Part II—The Industrial Engineer and Management Research

IN MANAGEMENT as elsewhere, research assures survival; it is the prerequisite for progress. What role do science and research play in day-by-day Industrial Engineering practice?

THE ROLE OF MANAGEMENT RESEARCH AND DEVELOPMENT

Many statements in just about every article published in each issue of the *Journal of Industrial Engineering* could be cited as an example. Uncounted others have an equal right to be named. In one or several ways, any solution of any problem has roots in knowledge developed by science through research.

True, in a number of situations, these roots do not comprise the sum total of the background from which the solution was shaped. Experience and judgment play an important part; no remark of this article wishes to depreciate this to even the slightest degree. But experience and judgment, in turn, are sharpened as science and research continue to unearth and codify know-how.

When used in managerial problems, research—in its pure and applied shape—was referred to as "Management Research and Development" in the first part of this sequence.[1] It is a function whose presence on organization charts is of rather recent origin. It is bound to appear ever more frequently, and I hope its scope will also expand.

On the strength of best current practice, Management Research and Development is today primarily employed as an auxiliary to planning and control (or review). At present, it has these three major tasks:

1. To process existing data.
2. To obtain additional information.
3. To investigate and study existing or future problems.

The first two assignments fall squarely into the "development" portion of Management Research and Development. As far as the third is concerned, this is also the case with by far too large a proportion of all projects which have appeared in the Industrial Engineering picture. Just about every one of them had as its purpose the "investigation and study of . . . problems" in the interest of *solving existing or future operating difficulties* or of *improving operational performance*. This clearly constitutes "applied research" or "development" work. To illustrate: Better communications within an organization are generally thought of as one of many possible ways by which operating results could be improved. Applied management research would make a highly useful contribution toward that end if it developed, for instance, means by which the effectiveness of communications could be measured.

The statement of the purpose of Management Research and Development which was quoted in the preceding paragraph from representative company manuals, makes it entirely possible, however, to think also in terms of an "investigation and study of . . . problems" with interest of *increasing management knowledge*. Such an interpretation would represent "pure research" efforts. Utilizing the same example of communication, pure research could concern itself, among other problems, with determining what basic factors make communications more effective.

Without the enlargement of its objective to include pure research, Management Research and Development would confine itself in too narrow a scope. This is true whether its task is viewed in the perspective of its future opportunities or whether it is compared with the realm

[1] This is the second part of a two article sequence on "Industrial Engineering and Science." It is also the sixth of the full series which endeavored to sketch the role of Industrial Engineering in these momentous years in the development of our branch of the engineering professions (4) (5) (6) (7) (8).

generally assigned to research and development in other fields.

Regardless of the location of a precise demarcation, both portions of research and development serve scientific as well as commercial aims by providing answers to the eternal question "why." We frequently know "what" happens; much less often can we explain "why" it does. Yet until we recognize the causes of the effect we want, we can not assure that even the best efforts will produce what we need.

Take the current (February 1961) business situation for example.[2] Obviously everyone would like to see economic activity turn upward again. But what will bring this about more lastingly, incentives for larger capital investments or spurs to increased consumer purchasing power?

We don't know; what is worse, so far the answers to this supremely important problem (which is posed here in oversimplified form) have been shaped mainly along political lines. Yet the platform of neither party could ever hope, in their present method of formulation, to gain the strength of an approach which bases itself on scientifically substantiated explanations.

The Industrial Engineer is vitally concerned with this phenomenon of the economy. For those whose tasks include corporate planning, such contributions must obviously be patterned to the expected economic climate. For others whose responsibilities concern, say, manufacturing, such knowledge is equally useful because it makes possible, for instance, the presentation of a work simplification or of other cost reduction programs *in advance of a business recession,* thus testifying, through facts rather than claims, to Industrial Engineering foresight and versatility.

In the most fundamental terms, the immense impact of research was brought home to me through an example for which I am indebted to Walter Scott. This eminent management consultant in Australia, past president of the international management organization CIOS, quotes an unknown author, in his book *Australia and the Challenge of Change,* as follows (9):

> Diamond Jim Brady, the affable free-spender half a century ago, lived in royal style. But he never heard of air-conditioning, foam rubber or nylon, high-octane or DDT, detergents or fluorescent lighting.
>
> "Yes," you say, "the world has changed."
>
> Well not exactly. The chemical elements, of which everything is composed, have been here since Adam. The world hasn't changed. *We just use it better.*

Research finds the reasons for existing phenomena or problems. It provides the foundation from which they can be conquered more fully.

APPLIED RESEARCH

1. *Processing existing data:* Decisions are materially strengthened whenever pertinent information can be made more meaningful. This calls for analysis and synthesis. With the easy wisdom of hindsight, it seems astonishing that statistics, a key analytical tool of science, entered the engineering scene so late.

When it appeared in Industrial Engineering, too few years ago, it took hold in a hurry. As early as 1953, the *Journal of Industrial Engineering* published a full page listing statistical techniques in Industrial Engineering applications (1). Today assembly lines and warehouses, showrooms and laboratories, construction sites and air terminals of progressive companies reverberate with battle cries such as:

.. normal distribution,
.. confidence and control limits,
.. tests of significant difference,
.. correlation and regression,
.. central tendency and dispersion.

Many a manager—and Industrial Engineer—find it a not too leisurely chase to catch up with the statistical know-how which he now needs. To many of us, this is entirely new material; to others, it brings back dim memories from college days which we would not have been too discontent to leave in oblivion.

Before this shock wave abated, a new force invaded Industrial Engineering. Its insignia were mathematical symbols, often of such strangeness that this writer who chose mathematics as his minor field in college (but some years ago!), is at times not certain whether he is holding the page right side up. The Industrial Engineer's vocabulary has become enriched with such terms as:

.. linear, quadratic or still other programming,
.. simulation and Monte Carlo theory,
.. information and game theory,
.. factors analysis and search theory,
.. servo and value theory,
.. queueing theory,
.. systems analysis.

In the hands of the more discriminating and knowing minds, each of these and indeed many other approaches have their more or less defined usefulness. They are applied to problems which the Industrial Engineer had long believed "fully solved" without advanced mathematics or statistics. Even before their advent in the past ten or twenty years at the most, we had courageously wrestled with problems of:

.. allocation of resources,
.. equipment scheduling and priorities on operational sequence,
.. machine breakdown and maintenance,
.. stock diversification and facilities obsolescence,
.. replacement parts and sources of supply,
.. warehouse and plant locations,
.. expenditure budgeting,
.. investment opportunities,
.. etc.

In many cases, the results were quite acceptable under

[2] In the hope that the situation may have changed a good bit by the time this appears in print, may I record that these thoughts are dictated January 9, 1961.

the easier conditons and demands of yesteryear's economy. In current and future, i.e., more complex situations, better approaches are necessary. In quite a few instances, mathematics can help provide more accurate and more economical solutions.

And then the computer knocked at the door. Its speed, its memory and its versatility are phenomenal. These capabilities made the use of another repertory of statistical and mathematical approaches feasible which would have remained doomed to unemployment in the presence of manual or less sophisticated calculating means. Even in as scanty a space as these columns, the computer deserves more comment. May I postpone it, though, until after we take a look at the other parts of the current assignments for the "development" portion of Management Research and Development.

2. *Obtaining additional information:* Good feedback assures utilization of every shred of useful information from the company's *own* experience. In many cases, we need additional facts from the outside. The most widely used approach to gathering such data is through surveys. Their objective is likely to be any event which can affect the organization's operations. Thus, even a cursory list would include:

.. consumer expenditures and income,
.. inventories,
.. industrial and other business activity,
.. population growth,
.. interest rates and money flow,
.. data on our own industry and on other fields of commercial activity,
.. governmental action (on taxes or labor legislation, patent or antitrust matters, etc.),
.. and many others.

A glimpse at the large number of possible sources increases the awareness of the magnitude of this task. Useful data are produced, for example, by:

.. government agencies,
.. trade associations,
.. banks and credit bureaus,
.. the literature.
.. universities,
.. management and professional societies,
.. foundations,
.. etc.

3. *Studying operating problems:* The boundaries of these efforts can be expanded as far as practical vision and foresight stretch. Every operation and every group, every ingredient of material or energy or human input as well as every criterion of performance output are possible candidates for useful "operational research."

May I first refer to the knowledge accumulating under the terms "Human Factors," or "Engineering Psychology," or "Bio-Technology." It aims at engineering *for*, not *of* human beings. It recognizes that the principal limitations often do not lie anymore, as before, in material strength or physical traits but rather in human performance as it expresses itself in speed or reliability, accuracy or in still other fashion.

Invaluable information is at our disposal through the research results also in non-technical sciences, in their knowledge of:

.. human characteristics and capabilities, such as
— vision and hearing,
— muscular strength,
— reaction time and perception,
— capacity for learning,
— individual or group reaction to demands.
.. the influence on these factors by the environment as exemplified by
— temperature and humidity,
— light, noise and color,
— vibration,
— pressure.

And some Industrial Engineers have made splendid use of this information, for instance,

.. in the designing of ventilated welding helmets.
.. through the development of protective suits for workers in magnesium or aluminum or steel mills.
.. by the arrangement of different break periods during morning and afternoon or in winter as against the summer months.

In every case, the results included smoother operations, better economic performance (cost or time-wise, for example), greater satisfaction on the part of the operators, a superior product and many other improvements.

As another typical example, I would like to point out the application of the results from electrical engineering research on the design of radio noise filters which was found to be highly useful in the reduction of inventory fluctuations.

Then there is the construction, by Industrial Engineers, of models which permit the study of such diversified areas as:

.. equipment scheduling in manufacturing,
.. inventory management,
.. Southern Pacific's freight car control,
.. United Air Lines' classic model of airport operations,
.. the Port of New York Authority's rush hour bus traffic,
.. the wholesale marketing setup of a metal products firm,
.. AMA's Top Executive Decision Making and other exercises at the Academy in Saranac Lake,
.. many military and civilian applications in logistics, materiel and numerous other phases.

Even the most crowded of all presentations of results achieved by Industrial Engineers through applied research would be incomplete without the mention of PERT (Program Evaluation and Review Technique) (3). Originally developed for the Polaris Fleet Ballistic Missile Program of the United States Navy just a couple of years ago, it is already in operation in a number of industrial concerns as well.

In the fourth article of the series, I emphasized the opportunities which Industrial Engineering has in as typical an engineering assignment as the measurement of different phases of managerial performance. PERT is an excellent example to prove that this admittedly difficult

assignment can be solved much more readily by enlisting research, if indeed it could ever be accomplished without it.

I also like to stress as unequivocally as the printed word can convey, that the appearance of mathematics is *not* the characteristic which identifies useful research. As *the* language of science, mathematics is likely to be represented in scientific endeavors; but it could be absent without necessarily impairing the value or character of the research effort.

Nor is the attack on a problem by a team rather than an individual another infallible clue that science has taken over the study of a problem. Again such joint approach is probable in the face of the huge complexity inherent in most "normal" situations or even in simplified models. It takes, more often than not, the combined knowledge of practitioners from different disciplines to assure the full impact of their individual contributions. Thus the Industrial Engineer is likely to find himself, in applied research, in the company of all kinds of representatives from other fields.

The crux of research remains, however, the faithful application of scientific methods, with their special mental attitude, "foremost in which is a reverence for facts" (2). In this lies also the limitation of applied research efforts in contemporary managerial practice because too many key factors have yet to be established factually. In turn, reducing this deficiency represents still another task for the Industrial Engineer. To some extent, he can remedy this situation in the pursuit of his own work. For the balance, he will turn, ever more encouraged we hope by his management, to the one activity whose very existence lies in the generation of knowledge, the "research" segment of Management Research and Development.

PURE RESEARCH—BRIDGE INTO TOMORROW

The full honor of the term "research" belongs only to those projects which produce hitherto unknown information. Perhaps the single most ominous indictment that could be brought against any discipline, is a lag in pure research projects. Ever more frequently, tomorrow's application will have to come from today's research.

For the country as a whole, 1960 was the first year in which expenditures for pure research appear to have reached one billion dollars when we count all conceivable and not just research effort in management. Even if this figure should turn out to be correct, it represents still only ten percent of the total research and development budget for the United States.

The inventory of pure Industrial Engineering research appears hardly adequate. True, there are notable projects all over the map. Foremost among these is perhaps one which, interestingly enough, is conducted outside the normal habitat of pure research, i.e. the colleges and universities.

I refer to System Development Corporation's "Mark I." Its model simulates a medium-sized manufacturing organization with every one of its major activities. The computer is programmed so as to permit literally hundreds of policies or procedures, of standards or plans to be tested individually for their effect. Thus it is possible, for instance, to ascertain which, if any, operating results change—and how—when we alter the setup in one respect. We can shift, say, the responsibility for deciding the sequence in order processing from the clerk to his supervisor; or we could substitute one decision rule for reordering stock with another. In each case, the effect of one change can be observed by reading out whatever indicators appear needed for evaluation.

Of course there are other examples of such far-sighted expansion of creative science into the realms of management in general and of Industrial Engineering in particular. But as a whole, it is again the absence of formidable progress in this area which makes it such an inviting opportunity for the Industrial Engineer to stimulate scientists to do this work whose results will help us no end.

What is needed to bring about these developments rests squarely upon the conscience of every one involved:

> .. Those engaged in research must realize that business can afford unqualified support of pure research only to a limited extent. This would leave the task largely in the hands of colleges and universities, foundations and possibly the government. Beyond that, even the largest corporation can afford participation, support or encouragement only when reasonable prospects for commercial usefulness exist.
>
> .. Those to whom research findings would bring, first, additional knowledge and then profits, must recognize research as perhaps the weightiest of all preparations for the future.
>
> .. A professional society like AIIE could serve well as catalyst on both fronts. Preliminary steps toward those ends have been taken; we hope the future will show that they go in the right direction and have been sufficient.

POINT OF DECISION

Industrial Engineering backstops management in most of its key decision areas. In a series on Industrial Engineering in 1961, it is altogether fitting for one of the youngest yet most promising fixtures on the managerial stage, the computer, to make a return appearance.

At a UNESCO-sponsored Conference on Information Processing in Paris in 1959, Dr. Edward Teller made this observation:

> The electronic computer has developed to the point at which it could not only count and memorize but also become teachable and acquire experience, form judgment, take the initiative as well as develop emotions.

We are thus faced with the likelihood that a machine can parallel two of the characteristics which, until a very short time ago, were considered to be the exclusive domain of a human being—creativity and emotions. Does this place us at the threshold of a far-reaching displacement of people through machines—now not only on the assembly line or in routine work but in creative effort as well?

Sufficient facts are not available today to permit me to prove my conclusions scientifically; and it does not help this predicament that everybody else is in that very same situation. It exists because we know how the machine operates; but we can not yet explain how a human being thinks or creates:

.. Do we create new things by putting different constellations together through selecting different components from the same old inventory of recollections which is stored in our memory, consciously or not?

.. Or do we create, through the spark of genius, something truly new that has at least some components which did not previously exist in our brains' filing cabinet?

If the first were the case, machines which exist, could take our place today. If the second is true, we may be safe—for a while.

Every fiber of my heart revolted at the thought that even in the better of these two situations, an undetermined grace period was the only safeguard for my continued usefulness. I checked the available facts again; they persisted; sentiment could disapprove of them but did not make them disappear.

However as so often in human life, the problem was not just simply two-sided, an either-or-choice of black-or-white. Another answer suggested itself before long: If homo sapiens should have created a competitor to himself, in the shape of skilfully arranged transistor circuits which his own imagination put together in a computer, he need not accept this achievement as setting a limit on his own development.

A novelty may be permitted to make obsolete another thing if the newcomer has greater value; a large portion of any Industrial Engineer's daily work aims at this very goal. At no time, however, must a novel thing make obsolete a human being *unless he consents.* Rather than to acquiesce to such doom, we have the obligation to vanquish threats from innovations by raising ourselves above them—sky-high.

This challenge is great. It demands persistent professional growth. Yet it is fully within our reach because all we have to do to accomplish this, is to use our talents. They have all the capacity that should ever be needed because they are a loan by the Lord.

I am now supremely confident that this is the road which lies ahead:

.. With the help of scientific research, the New Industrial Engineer will sharpen his knowledge and experience, his judgment and his power to think and create.

.. His designs will bring progressively finer solutions into the steadily growing scope of his managerial responsibilities.

.. The computer will remain a servant—its own impressive advance outstripped by the even steeper growth of its keeper.

What magnificent opportunities such a situation offers to all of us! At no time has the Industrial Engineer had so many chances to put his abilities to work as he has today. In 1965, they will be even greater. And in 1975—just fourteen years hence—they will have grown so much that the giant problems of today will appear, in retrospect, as minor irritations whose main usefulness was to incite us to ever greater accomplishments.

I want to make it a matter of record that this conclusion is not a dream picture of my imagination. It is the reaction which it has been my good fortune to observe in AIIE meetings throughout this country and Canada. When we talked about the vast opportunities which beckon and about the likelihood that Industrial Engineers will grasp them, a look around each audience gave the unequivocal answer: "We shall!"

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RECENT READABLES

NEW PUBLICATIONS

"Tax Depreciation Here and Abroad," George Terborgh, January 11, 1961.

George Terborgh's latest research study in the field of depreciation policy is of special interest at this time. It dramatically documents the disparity between tax depreciation here and abroad.

It is a comparison of depreciation allowances in the United States with seven other industrial countries—Great Britain, Canada, West Germany, Sweden, France, Italy, and Japan.

Copies of this review are available at 25¢ per copy from: Machinery and Allied Products Institute, 1200 Eighteenth Street, N.W., Washington 6, D.C.

AUTOMATION

"Automate Shop Paperwork," R. W. Christian, FACTORY, *February, 1961.*

A comprehensive review of the various electronic systems available to record shop production. The author presents the pros and the cons of such machines generally and also cites savings achieved in various actual installations. *(I. L. Haines, Lukens Steel Company)*

"Production Counting," M. F. Roberts, FACTORY, *April, 1960.*

A rundown of production counting devices used by a variety of manufacturers. Included are photographs and explanation of devices. *(A. L. Friedrichs, Ethyl Corporation)*

COST CONTROL

"Competing Companies Work Together to Overcome Profit Squeeze," Gordon Weyermuller, CHEMICAL PROCESSING, *January, 1961.*

After manpower survey provides information on number of employees in specific functions at individual companies, representatives meet together to compare notes and see how efficiency can be improved. Does it pay off? One company expects to save one million dollars a year for a single operation!

ENGINEERING ECONOMY

"N.A.A. Research Report No. 35," Alan G. Bates,* THE ENGINEERING ECONOMIST, *January-February, 1961.*

This article review has two objectives. First, a review and commentary is given of the N.A.A. report itself. Then a critical analysis is presented on the use of return on capital in performance measurement, with the intent of focusing attention on what appear to be serious inadequacies in this use.

"A Method of Replacement Analysis," J. A. Nordin, THE ENGINEERING ECONOMIST, *January-February, 1961.*

The replacement-analysis method, called the total-discounted-expenditure (TDE) method, is applied only to simple conditions, but ways of dealing with complications are outlined. A significant part of the case for the method is the contention that it can deal with certain complexities better than the leading current methods can.

"The Depreciation Dilemma, Jay Gossett, CHEMICAL PROCESSING, *January, 1961.*

Unrealistic useful lives of federal depreciation policies confiscate capital, deter modernization, cripple business in meeting foreign competition, complain critics; yet reform proposals bog down amid apathy and misunderstanding.

"How ADM Chose Peoria," Maurice Fulton, CHEMICAL PROCESSING, *January, 1961.*

Just how complex the selection of a location of a plant to produce a broad line of chemicals to be distributed nationally is shown by a behind-the-scenes look at how Archer-Daniels-Midland Co. selected Peoria, Illinois as the site for its new, modern multi-million-dollar chemical complex now being built.

GENERAL

"13 Ways to Update Your PM Program," A. F. DeLong, FACTORY, *February, 1961.*

Whether you have a planned maintenance program at your plant or are, only now, considering one, this list of pointers should prove extremely helpful. This writer emphasizes the fact that PM is a dynamic concept and thus needs constant updating. *(I. L. Haines, Lukens Steel Company)*

"Staff Men Should Speak Up," W. B. Carter, FACTORY, *February, 1961.*

"Six rules for staff men" that will help them make more important contributions to their company's efficiency. Pay off comes only when suggested improvements are actually made and in operation. *(I. L. Haines Lukens Steel Company)*

"The Incentive System in the Soviet Union," Charles S. Stevenson, ADVANCED MANAGEMENT, *January, 1961.*

What the Soviets have done and are doing with incentives suggests, even more pointedly than their success in such aristocratic events in the Olympics as fencing, sailing and dressage, that they have more than a casual interest in events in the capitalistic world.

"Know Your Bearable Margin of Error," Carl A. Bimson, THE OFFICE, *January, 1961.*

This article discusses a management principle that often needs more objective consideration than it gets: the margin of error which is acceptable in each management decision and that which is not.

"Manual Timing Techniques," G. G. Wiley and J. W. Heuer, INSTRUMENTS AND CONTROL SYSTEMS, *October, 1960.*

Basic manual timing techniques and equipment are presented including cumulative timing, instantaneous sequential timing, hours indications, split action timing, and recording techniques. *(A. L. Friedrichs, Ethyl Corporation)*

JOB EVALUATION

"Management Neglect Can Ruin A Good Job Evaluation Program," THE IRON AGE, *December 15, 1960.*

It is paradoxical that top management executives too often are responsible for the demise of a good program simply because they have failed to devote enough attention to the program once it has been installed.

MATERIALS HANDLING

"Handling System Stretches Storage, Output at International Latex," FACTORY, *February, 1961.*

A brief description of a material handling system in a distribution center. Article contains a complete flow diagram of the plant

and photos of major stations. *(I. L. Haines, Lukens Steel Company)*

"The True Cost of Packaging," William F. Jacobi, MATERIALS HANDLING ENGINEERING, *December 19, 1960.*

The cost of packaging is much more than the cost of the package. All related costs must be included to give the true picture and to reveal where savings can be made. *(J. P. Fagan, Ethyl Corporation)*

"Fully Automatic Storage for Pre-Assembly Work," Dick Dietz, MATERIALS HANDLING ENGINEERING, *December, 1960.*

The ultimum in storage automation. A push button storage system provides maximum accessibility in a minimum of time and allows items to be stored from floor to ceiling. *(J. P. Fagan, Ethyl Corporation)*

"Power- and Free-Conveyor Lines Speed Auto-Type Assemblies," THE IRON AGE, *December 22, 1960.*

Materials handling can mushroom into a major headache if different assemblies are processed on the same line.

Here's how a company solved its product-mix problems with an overhead-handling system.

OPERATIONS RESEARCH

"Operations Research: A Progress Report," James C. Hetrick, CHEMICAL ENGINEERING, *January 23, 1961.*

This paper discusses the coming of age of this valuable management tool. Problem formulation by the "grasshopper" technique is explained and examples of operations research's aid in solving problems in bulk storage, Capital investment and rotating shift assignments are given. A list of areas where operations research has proved useful is also presented *(J. P. Fagan, Ethyl Corporation)*

SYSTEMS AND PROCEDURES

"Atorgenics, The Science of Organization," B. M. M. Carpendale, ADVANCED MANAGEMENT, *February, 1961.*

In spite of numerous so-called theories and principles of organization, it is astonishing how little real ingenuity has been shown in an organization's design, considering how much we blame them for our difficulties.

"Cost Reduction for the Large and Small Office," Harold B. Maynard, THE OFFICE, *January, 1961.*

Several members of the Association of Consulting Management Engineers have consistently advocated that a careful methods analysis, using tested Industrial Engineering techniques be undertaken before any decision is made on whether or not to automate. It is obviously sounder to identify unnecessary work and eliminate it altogether than install a machine to do it more quickly.

"AMA to Stress the 'How's' of IDP," OFFICE MANAGEMENT, *March, 1960.*

Conference in New York considers ways to integrate data processing into total systems—and how to do it at less cost.

"How Much Does Your 'Alibi System' Cost You?" Maurice F. Ronayne, OFFICE MANAGEMENT, *March, 1960.*

An error is made. The boss is alarmed. An elaborate control is set up—permanently. The cost? Expensive. . . .

"Conveyors—Complement to IDP," Robert H. Cain, OFFICE MANAGEMENT, *March, 1960.*

Management has sped the processing of data, but has not always sped papers from desk to machine and back.

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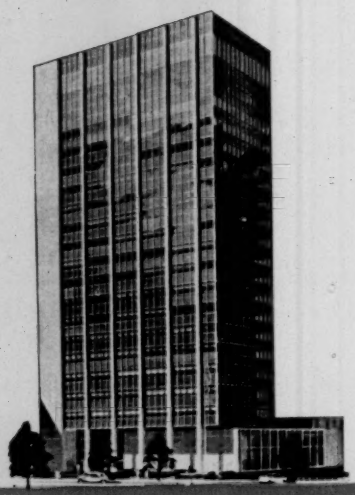

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